

LAMPIRAN I

STANDAR ASTM G 39-99

STANDARD PRACTICE FOR PREPARATION AND USE OF BENT-BEAN STRESS-CORROSION TEST SPECIMEN





Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens¹

This standard is issued under the fixed designation G 39; 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

1.1 This practice covers procedures for designing, preparing, and using bent-beam stress-corrosion specimens.

1.2 Different specimen configurations are given for use with different product forms, such as sheet or plate. This practice applicable to specimens of any metal that are stressed to levels less than the elastic limit of the material, and therefore, the applied stress can be accurately calculated or measured (see Note 1). Stress calculations by this practice are not applicable to plastically stressed specimens.

NOTE 1—It is the nature of these practices that only the applied stress can be calculated. Since stress-corrosion cracking is a function of the total stress, for critical applications and proper interpretation of results, the residual stress (before applying external stress) or the total elastic stress (after applying external stress) should be determined by appropriate nondestructive methods, such as X ray diffraction (1).²

1.3 Test procedures are given for stress-corrosion testing by exposure to gaseous and liquid environments.

1.4 The bent-beam test is best suited for flat product forms, such as sheet, strip, and plate. For plate material the bent-beam specimen is more difficult to use because more rugged specimen holders must be built to accommodate the specimens. A double-beam modification of a four-point loaded specimen to utilize heavier materials is described in 10.5.

1.5 The exposure of specimens in a corrosive environment is treated only briefly since other practices deal with this aspect, for example, Specification D 1141, and Practices G 30, G 36, G 44, G 50, and G 85. The experimenter is referred to ASTM Special Technical Publication 425 (2).

1.6 The bent-beam practice generally constitutes a constant strain (deflection) test. Once cracking has initiated, the state of stress at the tip of the crack as well as in uncracked areas has changed, and therefore, the known or calculated stress or strain values discussed in this practice apply *only* to the state of stress existing *before* initiation of cracks.

1.7 The values stated in SI units are to be regarded as standard. The inch-pound equivalents in parentheses are pro-

vided for information.

1.8 *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.* (For more specific safety hazard information see Section 7 and 12.1.)

2. Referenced Documents

2.1 ASTM Standards:

D 1141 Specification for Substitute Ocean Water³

G 30 Practice for Making and Using U-Bend Stress Corrosion Test Specimens⁴

G 36 Practice for Performing Stress-Corrosion Cracking Tests in a Boiling Magnesium Chloride Solution⁴

G 44 Practice for Evaluating Stress Corrosion Cracking Resistance of Metals and Alloys by Alternate Immersion in 3.5 % Sodium Chloride Solution⁴

G 50 Practice for Conducting Atmospheric Corrosion Tests on Metals⁴

G 85 Practice for Modified Salt Spray (Fog) Testing⁴

2.2 NACE Documents:⁵

NACE TM0177-96 Laboratory Testing of Metals for Resistance to Specific Forms of Environmental Cracking in H₂S Environments

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *stress-corrosion cracking*—a cracking process requiring the simultaneous action of a corroder and sustained tensile stress. This excludes corrosion-reduced sections that fail by fast fracture. It also excludes intercrystalline or transcrystalline corrosion which can disintegrate an alloy without either applied or residual stress.

3.1.2 *cracking time*—the time elapsed from the inception of test until the appearance of cracking.

3.1.2.1 *Discussion*—1 The test begins when the stress is applied and the stressed specimen is exposed to the corrosive environment, whichever occurs later.

3.1.2.2 *Discussion*—2 The specimen is considered to have

¹ This practice is under the jurisdiction of ASTM Committee G-1 on Corrosion of Metals, and is the direct responsibility of Subcommittee G01.06 on Stress Corrosion Cracking and Corrosion Fatigue.

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² The boldface numbers in parentheses refer to the list of references appended to this practice.

³ *Annual Book of ASTM Standards*, Vol 11.02.

⁴ *Annual Book of ASTM Standards*, Vol 03.02.

⁵ Available from National Association of Corrosion Engineers, Int., P. O. Box 218340, Houston, TX 77218–8340.

failed when cracks are detected. Presence of cracks can be determined with or without optical, mechanical, or electronic aids. However, for meaningful interpretation, comparisons should be made only among tests employing crack detection methods of equivalent sensitivity.

4. Summary of Practice

4.1 This practice involves the quantitative stressing of a beam specimen by application of a bending stress. The applied stress is determined from the size of the specimen and the bending deflection. The stressed specimens then are exposed to the test environment and the time required for cracks to develop is determined. This cracking time is used as a measure of the stress-corrosion resistance of the material in the test environment at the stress level utilized.

5. Significance and Use

5.1 The bent-beam specimen is designed for determining the stress-corrosion behavior of alloy sheets and plates in a variety of environments. The bent-beam specimens are designed for testing at stress levels below the elastic limit of the alloy. For testing in the plastic range U-bend specimens should be employed (see Practice G 30). Although it is possible to stress bent-beam specimens into the plastic range, the stress level cannot be calculated for plastically stressed three- and four-point loaded specimens as well as the double-beam specimens. Therefore, the use of bent-beam specimens in the plastic range is not recommended for general use.

6. Apparatus

6.1 *Specimen Holders*—Bent-beam specimens require a specimen holder for each specimen, designed to retain the applied stress on the specimen. Typical specimen holder configurations are shown schematically in Fig. 1.

NOTE 2—The double-beam specimen, more fully described in 10.5, is self-contained and does not require a holder.

NOTE 3—Specimen holders can be modified from the constant deformation type shown in Fig. 1 to give a constant-load type of stressing. For instance, the loading bolt can be supplanted by a spring or dead-weight arrangement to change the mode of loading.

6.1.1 The holder shall be made of a material that would withstand the influence of the environment without deterioration or change in shape.

NOTE 4—It should be recognized that many plastics tend to creep when subjected to sustained loads. If specimen holders or insulators are made of such materials, the applied stress on the specimen may change appreciably with time. By proper choice of holder and insulator materials, however, many plastics can be used, especially in short-time tests.

6.1.2 When the stress-corrosion test is conducted by immersion in an electrolyte, galvanic action between specimen and holder (or spacer) shall be prevented (see Note 5). This is accomplished by (1) making the holder of the same material as the individual specimens, (2) inserting electrically insulating materials between specimen and holder at all points of contact (see Note 4), (3) making the entire holder out of a nonmetallic material (see Note 4), or (4) coating the holder with an electrically nonconducting coating that effectively prevents contact between holder and electrolyte.

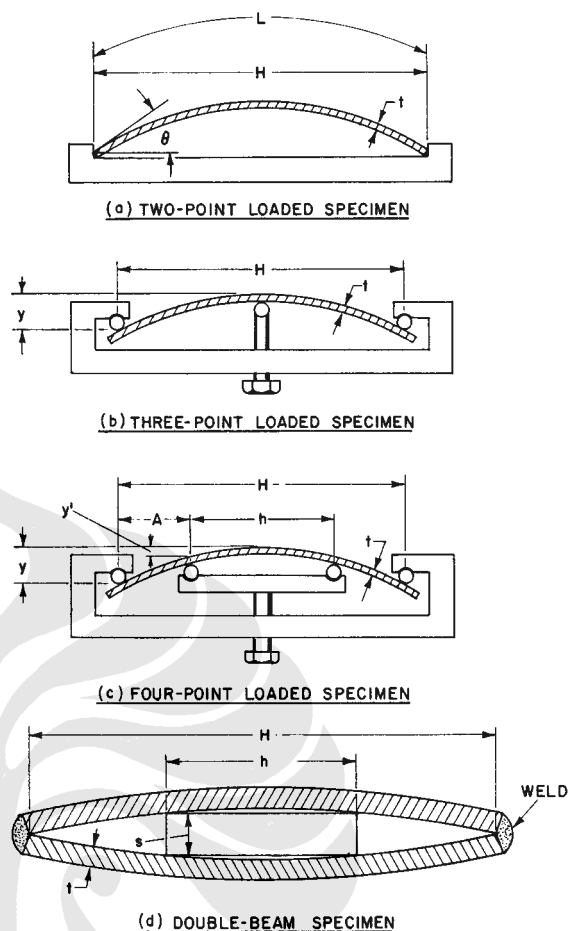


FIG. 1 Schematic Specimen and Holder Configurations

6.1.3 Crevice corrosion may occur in an electrolyte at contact points between specimen and holder (or spacer). In these instances the critical areas should be packed with a hydrophobic filler (such as grease or wax).

NOTE 5—In atmospheres (gas) galvanic action between specimen and holder either does not exist or is confined to a very small area as experienced in outdoor exposure tests.

6.2 *Stressing Jigs*—Three-point and four-point loaded specimen holders, Fig. 1 (b and c), contain a stressing feature in the form of a loading screw. To stress two-point loaded specimens (Fig. 1(a)), a separate stressing jig shall be used. A convenient stressing jig is shown in Fig. 2.

NOTE 6—The double-beam specimen, described in 10.5, requires a mechanical or hydraulic stressing frame (a universal tension testing machine can also be used) as well as welding equipment.

6.3 *Deflection Gages*—Deflection of specimens is determined by separate gages or by gages incorporated in a loading apparatus as shown in Fig. 3. In designing a deflection gage to suit individual circumstances care must be taken to reference the deflection to the proper support distance as defined in 10.2-10.5.

7. Hazards

7.1 Bent-beam specimens made from high-strength materials may exhibit high rates of crack propagation and a specimen



FIG. 2 Stressing Jig and Two-Point Loaded Specimen with Holder (approximately 1/4 actual size)

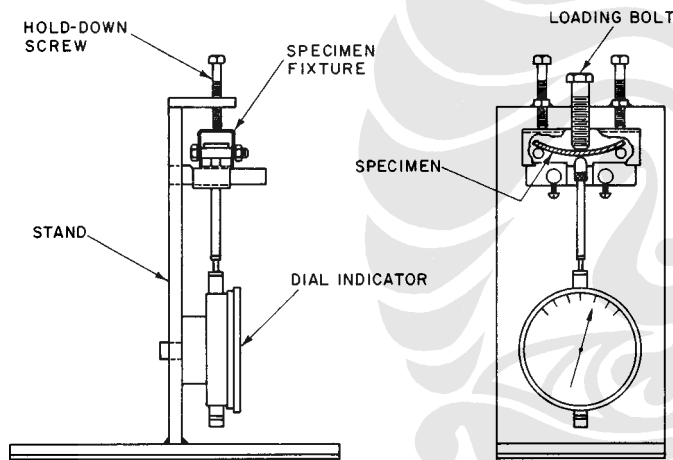


FIG. 3 Specimen Loading Apparatus for Three-Point Loaded Beam Specimens with Integral Deflection Gage

may splinter into several pieces. Due to high stresses in a specimen, these pieces may leave the specimen at high velocity and can be dangerous. Personnel installing and examining specimens should be cognizant of this possibility and be protected against injury.

8. Sampling

8.1 Test specimens shall be selected so that they represent the material to be tested. In simulating a service condition, the direction of load application in the specimen shall represent the anticipated loading direction in service with respect to processing conditions, for example, rolling direction.

8.2 Paragraphs 7.4 and 7.5 deal specifically with specimen selection as related to the original material surface.

9. Test Specimen

9.1 The bent-beam stress-corrosion specimens shall be flat strips of metal of uniform, rectangular cross section, and uniform thickness.

9.2 The identification of individual specimens should be permanently inscribed at each end of the specimen because this is the area of lowest stress and cracking is not expected to be initiated by the identification markings. If stenciling is used for identification, this shall be done only on softened material before any hardening heat treatments to prevent cracking in the stenciled area. Care must be taken to prevent the identification from being obliterated by corrosion.

9.3 Mechanical properties should be determined on the same heat-treatment lot from which stress-corrosion specimens are obtained.

9.4 The specimens can be cut from sheet or plate in such a fashion that the original material surface is retained. This procedure is recommended when it is desired to include the effect of surface condition in the test.

9.5 If, however, it is desired that surface conditions should not influence the test results of several materials with different surface conditions, the surfaces of all specimens must be prepared in the same way. It is recommended that grinding or machining to a surface finish of at least 0.7 μm (30 μin.) and to a depth of at least 0.25 mm (0.01 in.) be utilized for surface preparation. It is desirable to remove the required amount of metal in several steps by alternately grinding opposite surfaces. This practice minimizes warpage due to residual stresses caused by machining. All edges should be similarly ground or machined to remove cold-worked material from previous shearing. Chemical or electrochemical treatments that produce hydrogen on the specimen surface must not be used on materials that may be subject to embrittlement by hydrogen or that react with hydrogen to form a hydride.

9.6 Immediately before stressing, the specimens should be degreased and cleaned to remove contamination that occurred during specimen preparation. Only chemicals appropriate for the given metal or alloy should be used. Care must be exercised not to contaminate cleaned specimens. Also, it is suggested that specimens be examined for cracks before exposure to the test environment.

10. Stress Calculations

10.1 The equations given in this section are valid only for stresses below the elastic limit of the material. At stresses above the elastic limit but below the engineering yield strength (0.2 % offset) only a small error results from use of the equations (see Note 1). The equations must not be used above the yield strength of the material. The following paragraphs give relationships used to calculate the maximum longitudinal stress in the outer fibers of the specimen convex surface. Calculations for transverse stress or edge-to-edge variation of longitudinal stress are not given; the specimen dimensions are chosen to minimize these stresses consistent with convenient use of the specimens. The specimen dimensions given here can be modified to suit specific needs. However, if this is done the approximate specimen proportions should be preserved to give a similar stress distribution (for instance, if the length is doubled the width should be doubled also).

10.1.1 When specimens are tested at elevated temperatures, the possibility of stress relaxation should be investigated. Relaxation can be estimated from known creep data for the specimen, holder, and insulating materials. Differences in

thermal expansion also should be considered.

10.1.2 The applied stress is determined by specimen dimensions and the amount of bending deflection. Thus, the errors in the applied stress are related to those inherent in the use of measuring instruments (micrometers, deflection gages, strain gages, and so forth). For the two-point loaded specimens, most measured values lie within 5 % of the values calculated in accordance with the procedures given in 10.2.1-10.2.3, as reported by Haaijer and Loginow (4). The calculated stress applies only to the state of stress before initiation of cracks. Once cracking is initiated, the stress at the tip of the crack, as well as in uncracked areas, has changed.

10.2 *Two-Point Loaded Specimens*—This specimen can be used for materials that do not deform plastically when bent to $(L - H)/H = 0.01$ (see section 10.2.5). The specimens shall be approximately 25 by 254-mm (1 by 10-in.) flat strips cut to appropriate lengths to produce the desired stress after bending as shown in Fig. 1(a).

10.2.1 Calculate the elastic stress in the outer fiber at midlength of the two-point loaded specimens from relationships derived from a theoretically exact large-deflection analysis (4), as follows:

$$\epsilon = 4(2E - K) \left[\frac{k}{2} - \frac{2E - K}{12} \left(\frac{t}{H} \right) \right] \frac{t}{H} \quad (1)$$

and

$$(L - H)/H = [K/2E - K] - 1 \quad (2)$$

where:

- L = length of specimen,
- H = distance between supports (holder span),
- t = thickness of specimen,
- ϵ = maximum tensile strain,
- $K = \int_0^{\pi/2} (1 - k^2 \sin^2 z)^{-1/2} dz$ (complete elliptic integral of the first kind),
- $E = \int_0^{\pi/2} (1 - k^2 \sin^2 z)^{1/2} dz$ (complete elliptic integral of the second kind),
- $k = \sin \theta/2$,
- θ = maximum slope of the specimen, that is, at the end of the specimen, and
- z = integration parameter (4).

10.2.2 The mathematical analysis establishes that Eq 1 and Eq 2 define the relationship between the strain ϵ and $(L - H)/H$ in parameter form. The common parameter in these equations is the modulus k of the elliptic integrals. Thus, the following procedure can be used to determine the specimen length L that is required to produce a given maximum stress σ :

10.2.2.1 Divide the stress σ by the modulus of elasticity E_m to determine the strain ϵ .

$$\epsilon = \sigma/E_m$$

10.2.2.2 From Eq 1 determine the value of k corresponding to the required value of ϵ .

10.2.2.3 By using appropriate values of k evaluate Eq 2 for L . To facilitate calculations a computer can be used to generate a table for a range of strain ϵ and H/t with resultant values of $(L - H)/H$.

10.2.3 Calculate the deflection of the specimen as follows:

$$y/H = k/(2E - K) \quad (3)$$

where:

y = maximum deflection.

The other quantities are given in 10.2.1.

This relationship can be used as a simple check to ensure that the maximum stress does not exceed the proportional limit. If it should exceed the proportional limit, the measured deflection will be greater than that calculated from Eq 3.

10.2.4 As an alternative method the following approximate relationship can be used for calculating specimen length:

$$L = (ktE/\sigma) \sin^{-1} (H\sigma/ktE) \quad (4)$$

where:

- L = specimen length,
- σ = maximum stress,
- E = modulus of elasticity,
- H = holder span,
- t = thickness of specimen, and
- $k = 1.280$, an empirical constant.

This equation can be solved by computer, by trial and error, or by using a series expansion of the sine function. Eq 4 shall be used only when the quantity $(H\sigma/ktE)$ is less than 1.0.

10.2.5 Choose specimen thickness and length and holder span to obtain a value for $(L - H)/H$ of between 0.01 and 0.50, thus keeping the error of stress within acceptable limits. A specimen thickness of about 0.8 to 1.8 mm (0.03 to 0.07 in.) and a holder span of 177.8 to 215.9 mm (7.00 to 8.50 in.) has been very convenient when working with very high strength steels and aluminum alloys with applied stresses ranging from about 205 MPa (30 ksi) for aluminum to 1380 MPa (200 ksi) for steel. The specimen dimensions given here can be modified to suit specific needs. However, if this is done, approximate dimensional proportions shall be preserved.

10.2.6 In two-point loaded specimens the maximum stress occurs at midlength of the specimen and decreases to zero at specimen ends.

10.2.7 The two-point loaded specimen is preferred to three-point loaded specimens because in many instances crevice corrosion of the specimen occurs at the central support of the three-point loaded specimen. Since this corrosion site is very close to the point of highest tension stress, it may cathodically protect the specimen and prevent possible crack formation or cause hydrogen embrittlement. Furthermore, the pressure of the central support at the point of highest load introduces biaxial stresses at the area of contact and could introduce tension stresses where normally compression stresses are present.

NOTE 7—Occasionally two-point loaded specimens having a nonuniform cross section are used for special purposes. A description of such a specimen is given by Wilson and Spier (5).

10.3 *Three-Point Loaded Specimens*—The specimen shall be a flat strip typically 25 to 51-mm (1 to 2-in.) wide and 127 to 254-mm (5 to 10-in.) long. The thickness of the specimen is usually dictated by the mechanical properties of the material and the product form available. Support the specimen at the ends and bend the specimen by forcing a screw (equipped with a ball or knife-edge tip) against it at the point halfway between the end supports in a fashion shown in Fig. 1(b). The specimen dimensions given here can be modified to suit specific needs.

However, if this is done, approximate dimensional proportions shall be preserved.

10.3.1 Calculate the elastic stress at midspan in the outer fibers of three-point loaded specimens from the relationship:

$$\sigma = 6Et_y/H^2 \quad (5)$$

where:

- σ = maximum tensile stress,
- E = modulus of elasticity,
- t = thickness of specimen,
- y = maximum deflection, and
- H = distance between outer supports.

10.3.2 The above relationship is based on small deflections (y/H less than 0.1). In sheet gage bent-beam specimens the deflections are usually large, and thus, the relationship is only approximate. To obtain more accurate stress values, use for calibration a prototype specimen equipped with strain gages. This prototype should have the same dimensions as the test specimens and should be stressed in the same way.

10.3.3 In three-point loaded specimens the maximum stress occurs at midlength of the specimen and decreases linearly to zero at the outer supports.

10.3.4 For limitation in the use of three-point loaded specimens see 10.2.7.

10.4 *Four-Point Loaded Specimens*—The specimen shall be a flat strip typically 25 to 51-mm (1 to 2-in.) wide and 127 to 254-mm (5 to 10-in.) long. The thickness of the specimen is usually dictated by the mechanical properties of the material and the product form available. Support the specimen at the ends and bend the specimen by forcing two inner supports against it in a fashion shown in Fig. 1(c). The two inner supports shall be located symmetrically around the midpoint between the outer supports. The specimen dimensions given here can be modified to suit specific needs. However, if this is done, approximate dimensional proportions shall be preserved.

10.4.1 Calculate the elastic stress for the midportion of the specimen (between contact points of the inner support) in the outer fibers of four-point loaded specimens from the following relationship:

$$\sigma = 12Et_y/(3H^2 - 4A^2) \quad (6)$$

where:

- σ = maximum tensile stress,
- E = modulus of elasticity,
- t = thickness of specimen,
- y = maximum deflection (between outer supports),
- H = distance between outer supports, and
- A = distance between inner and outer supports.

The dimensions are often chosen so that $A = H/4$.

10.4.2 An alternative method of calculating the elastic stress between the inner supports is as follows:

$$\sigma = 4Et_y'/h^2 \quad (7)$$

where:

- h = distance between inner supports, and
- y' = deflection between inner supports.

(This equation is a special case of 10.4.1 when $A = 0$.)

10.4.3 The above relationships are based on small deflections (y/H less than 0.1). In sheet-gage bent-beam specimens

the deflections are usually large, and thus, the relationships are only approximate. To obtain more accurate stress values, use for calibration a prototype specimen equipped with strain gages. This prototype specimen should have the same dimensions as the test specimens and should be stressed in the same way.

10.4.4 In four-point loaded specimens the maximum stress occurs between the contact points with the inner supports; in this area the stress is constant. From the inner supports the stress decreases linearly toward zero at the outer supports.

10.5 *Double-Beam Specimen*—The specimen shall consist of two flat strips 25 to 51-mm (1 to 2-in.) wide and 127 to 254-mm (5 to 10-in.) long. Bend the strips against each other over a centrally located spacer until both ends of the specimens touch. Hold them in this position by welding the ends together as shown in Fig. 1(d) (see Note 8). An equivalent procedure for bolted specimens is described on pp. 319–321 of Ref (2).

NOTE 8—If the test is to be conducted in an electrolyte, the spacer shall be made of the same material as the specimen (or of an electrically nonconducting material such as glass, ceramic, and so forth) to prevent galvanic action between specimen and spacer. See also 6.1.2 and Note 4 and Note 5.

10.5.1 Calculate the elastic stress for the midportion of the specimen (between contact points of the spacer) in the outer fibers of the doublebeam specimens from the following relationship:

$$\sigma = \frac{3Et_s}{H^2[1 - (h/H)][1 + (2h/H)]} \quad (8)$$

where:

- σ = maximum tensile stress,
- E = modulus of elasticity,
- t = thickness of specimen strip,
- s = thickness of spacer,
- H = see Fig. 1(d), and
- h = length of spacer.

10.5.2 When the length of the spacer h is chosen so that $H = 2h$ the equation in 10.5.1 is simplified to:

$$\sigma = 3Et_s/H^2$$

10.5.3 The above relationships are based on small deflections (s/H being less than 0.2). In sheet-gage bent-beam specimens the deflections are usually large, and thus, the relationships are only approximate. To obtain more accurate stress values, use for calibration a prototype specimen equipped with strain gages. The prototype specimen should have the same dimensions as the test specimens and should be stressed in the same way.

10.5.4 In double-beam specimens the maximum stress occurs between the contact points with the spacer; in this area the stress is constant. From the contact with the spacer the stress decreases linearly toward zero at the ends of specimens.

11. Choice of Test Conditions

11.1 The purpose of stress-corrosion testing is to simulate on a small scale the conditions (materials, stress, and environment) that exist in an engineering application. The stresses in an engineering structure can be varied: operational (design)

stresses and residual stresses (from heat treatment or fabrication). Residual stresses are frequently the more important, primarily because current design practices and close control of processes have kept operational stresses well below the yield strength of the metal in use. On the other hand, magnitude and direction of residual stresses frequently are difficult to predict and also difficult to measure. Depending on the degree of restraint, residual stresses may even exceed the initial yield strength of the material.

11.2 Generally stress-corrosion testing falls into two broad categories: (1) evaluation of materials for a specific application and (2) comparison of the relative behavior of several materials or environments.

11.2.1 To evaluate materials for specific applications the testing conditions should be representative of the most severe conditions to which the materials would be subjected in service. Testing at nominal or design conditions could be misleading. An engineering structure, because of residual stresses, is expected to be stressed to its yield strength at some points even if the design stress for that structure is appreciably below yield strength. Thus, the use of the elastically stressed bent-beam specimens for materials evaluation is of limited value.

11.2.2 To compare materials or environments for relative stress-corrosion behavior, the test conditions may be only severe enough to produce varying degrees of cracking in the alloys of interest, in mechanical or thermal treatments used, or in sensitivity to specific environments investigated. By testing a set of specimens at a series of stress levels, the stress dependence of alloys can be assessed. The bent-beam specimen is very well suited for establishing the relative merits of several alloys for the relative severity of several environments.

11.3 Ideally, the environmental test conditions should be the same that would prevail in the intended use of the alloys. In choosing a set of test conditions, it is important that they (environment and stress) be well defined and reproducible. A detailed discussion is given by Loginow (6).

11.4 The presence of a machined notch in the middle of the tension side of a bent beam will induce a severe triaxial stress state at the root of the notch. The actual bending stress there

will be greater by a concentration factor dependent on the notch geometry, than the minimal test stress, and generally, may be expected to be in the range of plastic stain. Advantages of such a notched specimen include the probable localized cracking in the notch and an acceleration of failure. However, unless directly related to practical conditions of usage, misleading failures may ensue.

11.4.1 Another type of stress concentration at the site of two drilled holes located half way between the end supports of a three-point loaded bent beam has been used in the evaluation of metals for oilfield equipment. Details on the preparation and use of this specimen are described in NACE TM0177-96. Laboratory test data for carbon and low-alloy steels have been found to correlate with field data (7).

12. Specimen Exposure

12.1 Expose the stressed specimens to the environment (gaseous or liquid) of interest. This can be accomplished by mounting the specimen holders on appropriate racks and exposing the entire rack to the environment. A typical atmospheric exposure rack is shown in Fig. 4. As noted in 7.1, bent-beam specimens may break violently and thus cause injury. To protect personnel and to prevent specimen loss, drill holes in specimen ends and holders and secure the specimens by wires to their holders.

12.2 Determination of cracking time is a subjective procedure involving visual examination that under some conditions can be very difficult, as noted in Section 13, and depends on the skill and experience of the inspector.

12.3 *Laboratory Exposure of Bent Beams*— In both alternate and sustained immersion of bent beams, avoid galvanic corrosion between fixtures and specimens as discussed in 6.1.2 and Note 4 and Note 5. It should be recognized that, at points of contact between specimen and fixture, crevice corrosion may occur on some materials, which in turn may result in galvanic protection of the stressed area. If this condition occurs, either eliminate the crevice or consider a different kind of specimen. In alternate immersion, expose the specimen to allow complete drainage and drying of the surface. In immersion tests, arrange the specimens so as to prevent contact with



FIG. 4 Bent-Beam Specimens on Atmospheric Exposure Rack

each other. In both sustained and alternate immersion, the solution volume should be large enough to prevent depletion of corrosive agents. In elevated-temperature tests, make arrangements to reflux the solution to maintain a constant concentration.

12.4 *Atmospheric Exposure of Bent Beams*—Expose the specimens in an area that is representative of the atmospheric conditions of interest.

13. Inspection of Specimens

13.1 As continuous observation of specimens is usually impractical, inspect specimens for appearance of cracks at predetermined time intervals. These intervals are usually increased as the test progresses because the logarithms of observed cracking times are often normally distributed as described by Loginow (6) and by Booth et al (8).

13.2 Determine presence of cracks by visual observation, usually with the aid of a 5 to 10 power magnifying glass. If the specimen contains only one or a few cracks, the shape of the bend can be considerably changed, predominantly by kinking; this feature helps in identifying cracked specimens. However, if many cracks are present, a change in shape may not be apparent. It should also be noted that presence of voluminous corrosion products may obscure cracks, thus making a careful examination mandatory. In these instances metallographic sectioning of the specimen may be necessary to detect cracks.

14. Report

14.1 Results of stress-corrosion tests with bent-beam specimens are expressed as the time to produce failure by cracking or as the fraction of specimens that have cracked in a fixed time. In addition to the cracking time the following data shall be reported:

- 14.1.1 Specimen identification,
- 14.1.2 Material name or specification code,
- 14.1.3 Chemical composition,
- 14.1.4 Heat treatment,
- 14.1.5 Mechanical properties,
- 14.1.6 Type and orientation of specimen used and surface condition (hot rolled, cold rolled, machined, surface ground, and so forth),
- 14.1.7 Applied stress (and residual stress, if known),
- 14.1.8 Details of specimen preparation if different from those specified here (or if not specified),
- 14.1.9 Detailed description of test environment, and
- 14.1.10 Remarks concerning the size and appearance of cracks may be included.

15. Keywords

15.1 bent-beam; constant deformation; constant load; elastic strain; quantitative stress; stress-corrosion cracking; stress-corrosion test specimen

REFERENCES

- (1) *Measurement for Stress by X-Ray*, SAE Information Report TR-182, Society of Automotive Engineers, New York, NY.
- (2) *Symposium on Stress-Corrosion Testing*, ASTM STP 425, ASTM, 1967.
- (3) Snape, E., "Roles of Composition and Microstructure in Sulfide Cracking of Steel," *Corrosion*, Vol 24, 1968, pp. 261–282.
- (4) Haaijer, G., and Loginow, A. W., "Stress Analysis of Bent-Beam Stress-Corrosion Specimen," *Corrosion*, Vol 21, 1965, pp. 105–112.
- (5) Wilson, P. E., and Spier, E. E., "Nonlinear Bending of a Stress-Corrosion Specimen," *Journal of Engineering for Industry*, Vol 88, 1966, pp. 31–36.
- (6) Loginow, A. W., "Stress-Corrosion Testing of Alloys," *Materials Protection*, Vol 5, No. 5, May 1966, pp. 33–39.
- (7) Fraser, J. P., Eldredge, G. G., and Treseder, R. S., "Laboratory and Field Methods for Quantitative Study of Sulfide Corrosion Cracking," H₂S Corrosion in Oil and Gas Production—A Compilation of Classic Papers, Tuttle, R. N. and Kane, R. D., eds. (Houston, TX: NACE, 1981) p. 283. Original publication: *Corrosion* 14, 11 (1958) p. 517t.
- (8) Booth, F. F., Tucker, G. E. G., and Goddard, H. P., "Statistical Distribution of Stress-Corrosion Endurance," *Corrosion*, Vol 19, 1963, pp. 390t–395t.

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LAMPIRAN II

STANDAR ASTM G 1-03

***STANDARD PRACTICE FOR PREPARING,
CLEANING, AND EVALUATING CORROSION
TEST SPECIMENS***





Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens¹

This standard is issued under the fixed designation G 1; 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

1.1 This practice covers suggested procedures for preparing bare, solid metal specimens for tests, for removing corrosion products after the test has been completed, and for evaluating the corrosion damage that has occurred. Emphasis is placed on procedures related to the evaluation of corrosion by mass loss and pitting measurements. (**Warning**—In many cases the corrosion product on the reactive metals titanium and zirconium is a hard and tightly bonded oxide that defies removal by chemical or ordinary mechanical means. In many such cases, corrosion rates are established by mass gain rather than mass loss.)

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.* For specific precautionary statements, see 1 and 7.2.

2. Referenced Documents

2.1 ASTM Standards:

- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels²
- D 1193 Specification for Reagent Water³
- D 1384 Test Method for Corrosion Test for Engine Coolants in Glassware⁴
- D 2776 Test Methods for Corrosivity of Water in the Absence of Heat Transfer (Electrical Methods)⁵
- G 15 Terminology Relating to Corrosion and Corrosion Testing⁶
- G 16 Guide for Applying Statistics to Analysis of Corrosion Data⁶

¹ This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.05 on Laboratory Corrosion Tests.

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² *Annual Book of ASTM Standards*, Vol 01.03.

³ *Annual Book of ASTM Standards*, Vol 11.01.

⁴ *Annual Book of ASTM Standards*, Vol 15.05.

⁵ *Discontinued*, replaced by Guide G 96. See 1990 *Annual Book of ASTM Standards*, Vol 03.02.

⁶ *Annual Book of ASTM Standards*, Vol 03.02.

- G 31 Practice for Laboratory Immersion Corrosion Testing of Metals⁶
- G 33 Practice for Recording Data from Atmospheric Corrosion Tests of Metallic-Coated Steel Specimens⁶
- G 46 Guide for Examination and Evaluation of Pitting Corrosion⁶
- G 50 Practice for Conducting Atmospheric Corrosion Tests on Metals⁶
- G 78 Guide for Crevice Corrosion Testing of Iron Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments⁶

3. Terminology

- 3.1 See Terminology G 15 for terms used in this practice.

4. Significance and Use

4.1 The procedures given are designed to remove corrosion products without significant removal of base metal. This allows an accurate determination of the mass loss of the metal or alloy that occurred during exposure to the corrosive environment.

4.2 These procedures, in some cases, may apply to metal coatings. However, possible effects from the substrate must be considered.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.⁷ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type IV of Specification D 1193.

⁷ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

6. Methods for Preparing Specimens for Test

6.1 For laboratory corrosion tests that simulate exposure to service environments, a commercial surface, closely resembling the one that would be used in service, will yield the most meaningful results.

6.2 It is desirable to mark specimens used in corrosion tests with a unique designation during preparation. Several techniques may be used depending on the type of specimen and test.

6.2.1 *Stencil or Stamp*—Most metallic specimens may be marked by stenciling, that is, imprinting the designation code into the metal surface using hardened steel stencil stamps hit with a hammer. The resulting imprint will be visible even after substantial corrosion has occurred. However, this procedure introduces localized strained regions and the possibility of superficial iron contamination in the marked area.

6.2.2 Electric engraving by means of a vibratory marking tool may be used when the extent of corrosion damage is known to be small. However, this approach to marking is much more susceptible to having the marks lost as a result of corrosion damage during testing.

6.2.3 Edge notching is especially applicable when extensive corrosion and accumulation of corrosion products is anticipated. Long term atmospheric tests and sea water immersion tests on steel alloys are examples where this approach is applicable. It is necessary to develop a code system when using edge notches.

6.2.4 Drilled holes may also be used to identify specimens when extensive metal loss, accumulation of corrosion products, or heavy scaling is anticipated. Drilled holes may be simpler and less costly than edge notching. A code system must be developed when using drilled holes. Punched holes should not be used as they introduce residual strain.

6.2.5 When it is undesirable to deform the surface of specimens after preparation procedures, for example, when testing coated surfaces, tags may be used for specimen identification. A metal or plastic wire can be used to attach the tag to the specimen and the specimen identification can be stamped on the tag. It is important to ensure that neither the tag nor the wire will corrode or degrade in the test environment. It is also important to be sure that there are no galvanic interactions between the tag, wire, and specimen.

6.3 For more searching tests of either the metal or the environment, standard surface finishes may be preferred. A suitable procedure might be:

6.3.1 Degrease in an organic solvent or hot alkaline cleaner. (See also Practice G 31.)

NOTE 1—Hot alkalis and chlorinated solvents may attack some metals.

NOTE 2—Ultrasonic cleaning may be beneficial in both pre-test and post-test cleaning procedures.

6.3.2 Pickle in an appropriate solution if oxides or tarnish are present. In some cases the chemical cleaners described in Section 6 will suffice.

NOTE 3—Pickling may cause localized corrosion on some materials.

6.3.3 Abrade with a slurry of an appropriate abrasive or with an abrasive paper (see Practices A 262 and Test Method

D 1384). The edges as well as the faces of the specimens should be abraded to remove burrs.

6.3.4 Rinse thoroughly, hot air dry, and store in desiccator.

6.4 When specimen preparation changes the metallurgical condition of the metal, other methods should be chosen or the metallurgical condition must be corrected by subsequent treatment. For example, shearing a specimen to size will cold work and may possibly fracture the edges. Edges should be machined.

6.5 The clean, dry specimens should be measured and weighed. Dimensions determined to the third significant figure and mass determined to the fifth significant figure are suggested. When more significant figures are available on the measuring instruments, they should be recorded.

7. Methods for Cleaning After Testing

7.1 Corrosion product removal procedures can be divided into three general categories: mechanical, chemical, and electrolytic.

7.1.1 An ideal procedure should remove only corrosion products and not result in removal of any base metal. To determine the mass loss of the base metal when removing corrosion products, replicate uncorroded control specimens should be cleaned by the same procedure being used on the test specimen. By weighing the control specimen before and after cleaning, the extent of metal loss resulting from cleaning can be utilized to correct the corrosion mass loss.

NOTE 4—It is desirable to scrape samples of corrosion products before using any chemical techniques to remove them. These scrapings can then be subjected to various forms of analyses, including perhaps X-ray diffraction to determine crystal forms as well as chemical analyses to look for specific corrodants, such as chlorides. All of the chemical techniques that are discussed in Section 7 tend to destroy the corrosion products and thereby lose the information contained in these corrosion products. Care may be required so that uncorroded metal is not removed with the corrosion products.

7.1.2 The procedure given in 7.1.1 may not be reliable when heavily corroded specimens are to be cleaned. The application of replicate cleaning procedures to specimens with corroded surfaces will often, even in the absence of corrosion products, result in continuing mass losses. This is because a corroded surface, particularly of a multiphase alloy, is often more susceptible than a freshly machined or polished surface to corrosion by the cleaning procedure. In such cases, the following method of determining the mass loss due to the cleaning procedure is preferred.

7.1.2.1 The cleaning procedure should be repeated on specimens several times. The mass loss should be determined after each cleaning by weighing the specimen.

7.1.2.2 The mass loss should be graphed as a function of the number of equal cleaning cycles as shown in Fig. 1. Two lines will be obtained: AB and BC. The latter will correspond to corrosion of the metal after removal of corrosion products. The mass loss due to corrosion will correspond approximately to point B.

7.1.2.3 To minimize uncertainty associated with corrosion of the metal by the cleaning method, a method should be chosen to provide the lowest slope (near to horizontal) of line BC.

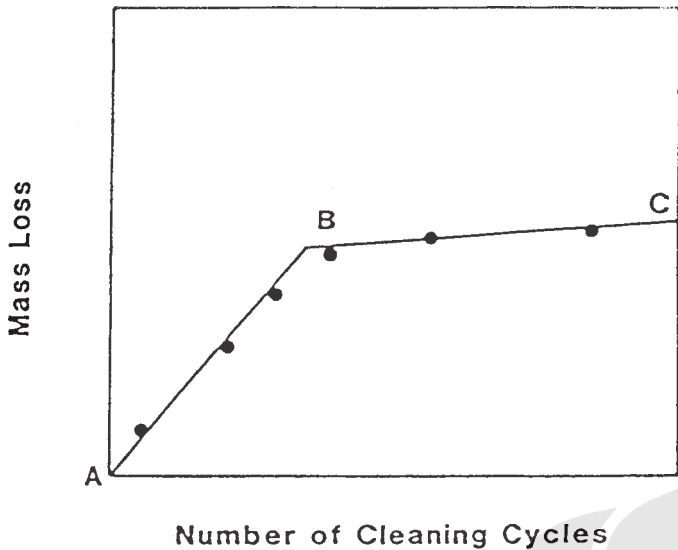


FIG. 1 Mass Loss of Corroded Specimens Resulting from Repetitive Cleaning Cycles

7.1.3 Repeated treatment may be required for complete removal of corrosion products. Removal can often be confirmed by examination with a low power microscope (for example, 7× to 30×). This is particularly useful with pitted surfaces when corrosion products may accumulate in pits. This repeated treatment may also be necessary because of the requirements of 7.1.2.1. Following the final treatment, the specimens should be thoroughly rinsed and immediately dried.

7.1.4 All cleaning solutions shall be prepared with water and reagent grade chemicals.

7.2 Chemical procedures involve immersion of the corrosion test specimen in a specific solution that is designed to remove the corrosion products with minimal dissolution of any base metal. Several procedures are listed in Table A1.1. The choice of chemical procedure to be used is partly a matter of trial and error to establish the most effective method for a specific metal and type of corrosion product scale. **(Warning—**These methods may be hazardous to personnel).

7.2.1 Chemical cleaning is often preceded by light brushing (non metallic bristle) or ultrasonic cleaning of the test specimen to remove loose, bulky corrosion products.

7.2.2 Intermittent removal of specimens from the cleaning solution for light brushing or ultrasonic cleaning can often facilitate the removal of tightly adherent corrosion products.

7.2.3 Chemical cleaning is often followed by light brushing or ultrasonic cleaning in reagent water to remove loose products.

7.3 Electrolytic cleaning can also be utilized for removal of corrosion products. Several useful methods for corrosion test specimens of iron, cast iron, or steel are given in Table A2.1.

7.3.1 Electrolytic cleaning should be preceded by brushing or ultrasonic cleaning of the test specimen to remove loose, bulky corrosion products. Brushing or ultrasonic cleaning should also follow the electrolytic cleaning to remove any loose slime or deposits. This will help to minimize any redeposition of metal from reducible corrosion products that would reduce the apparent mass loss.

7.4 Mechanical procedures can include scraping, scrubbing, brushing, ultrasonic cleaning, mechanical shocking, and impact blasting (for example, grit blasting, water-jet blasting, and so forth). These methods are often utilized to remove heavily encrusted corrosion products. Scrubbing with a nonmetallic bristle brush and a mild abrasive-distilled water slurry can also be used to remove corrosion products.

7.4.1 Vigorous mechanical cleaning may result in the removal of some base metal; therefore, care should be exercised. These should be used only when other methods fail to provide adequate removal of corrosion products. As with other methods, correction for metal loss due to the cleaning method is recommended. The mechanical forces used in cleaning should be held as nearly constant as possible.

8. Assessment of Corrosion Damage

8.1 The initial total surface area of the specimen (making corrections for the areas associated with mounting holes) and the mass lost during the test are determined. The average corrosion rate may then be obtained as follows:

$$\text{Corrosion Rate} = (K \times W)/(A \times T \times D) \quad (1)$$

where:

- K = a constant (see 8.1.2),
- T = time of exposure in hours,
- A = area in cm^2 ,
- W = mass loss in grams, and
- D = density in g/cm^3 (see Appendix X1).

8.1.1 Corrosion rates are not necessarily constant with time of exposure. See Practice G 31 for further guidance.

8.1.2 Many different units are used to express corrosion rates. Using the units in 7.1 for T , A , W , and D , the corrosion rate can be calculated in a variety of units with the following appropriate value of K :

Corrosion Rate Units Desired	Constant (K) in Corrosion Rate Equation
mils per year (mpy)	3.45×10^6
inches per year (ipy)	3.45×10^3
inches per month (ipm)	2.87×10^2
millimetres per year (mm/y)	8.76×10^4
micrometres per year ($\mu\text{m}/\text{y}$)	8.76×10^7
picometres per second (pm/s)	2.78×10^6
grams per square meter per hour ($\text{g}/\text{m}^2\text{-h}$)	$1.00 \times 10^4 \times D$
milligrams per square decimeter per day (mdd)	$2.40 \times 10^6 \times D$
micrograms per square meter per second ($\mu\text{g}/\text{m}^2\text{-s}$)	$2.78 \times 10^6 \times D$

NOTE 5—If desired, these constants may also be used to convert corrosion rates from one set of units to another. To convert a corrosion rate in units X to a rate in units Y , multiply by K_Y/K_X ; for example:

$$15 \text{ mpy} = 15 \times (2.78 \times 10^6)/(3.45 \times 10^6) \text{ pm/s} \quad (2)$$

8.1.3 In the case of sacrificial alloy coatings for which there is preferential corrosion of a component whose density differs from that of the alloy, it is preferable to use the density of the corroded component (instead of the initial alloy density) for calculating average thickness loss rate by use of Eq 1. This is done as follows: (1) cleaning to remove corrosion products only and determine the mass loss of the corroded component; (2) stripping the remaining coating to determine the mass of the uncorroded component; (3) chemical analysis of the stripping solution to determine the composition of the uncorroded

component; (4) performing a mass balance to calculate the composition of the corroded component; (5) using the mass and density of the corroded component to calculate the average thickness loss rate by use of Eq 1. An example of this procedure is given in Appendix X2.

The procedure described above gives an average penetration rate of the coating, but the maximum penetration for a multiphase alloy may be larger when the corroded phase is not uniformly distributed across the surface. In such cases, it is generally considered good practice to obtain a cross section through the corroded surface for microscopic examination. This examination will reveal the extent of selective corrosion of particular phases in the coating, and help in understanding the mechanism of attack.

8.2 Corrosion rates calculated from mass losses can be misleading when deterioration is highly localized, as in pitting or crevice corrosion. If corrosion is in the form of pitting, it may be measured with a depth gage or micrometer calipers with pointed anvils (see Guide G 46). Microscopical methods will determine pit depth by focusing from top to bottom of the pit when it is viewed from above (using a calibrated focusing knob) or by examining a section that has been mounted and metallographically polished. The pitting factor is the ratio of the deepest metal penetration to the average metal penetration (as measured by mass loss).

NOTE 6—See Guide G 46 for guidance in evaluating depths of pitting.

NOTE 7—See Guide G 78 for guidance in evaluating crevice corrosion.

8.3 Other methods of assessing corrosion damage are:

8.3.1 *Appearance*—The degradation of appearance by rusting, tarnishing, or oxidation. (See Practice G 33.)

8.3.2 *Mechanical Properties*—An apparent loss in tensile strength will result if the cross-sectional area of the specimen (measured before exposure to the corrosive environment) is reduced by corrosion. (See Practice G 50.) Loss in tensile strength will result if a compositional change, such as dealloying taking place. Loss in tensile strength and elongation will result from localized attack, such as cracking or intergranular corrosion.

8.3.3 *Electrical Properties*—Loss in electrical conductivity can be measured when metal loss results from uniform corrosion. (See Test Methods D 2776.)

8.3.4 *Microscopical Examination*—Dealloying, exfoliation, cracking, or intergranular attack may be detected by metallographic examination of suitably prepared sections.

9. Report

9.1 The report should include the compositions and sizes of specimens, their metallurgical conditions, surface preparations, and cleaning methods as well as measures of corrosion damage, such as corrosion rates (calculated from mass losses), maximum depths of pitting, or losses in mechanical properties.

10. Precision and Bias

10.1 The factors that can produce errors in mass loss measurement include improper balance calibration and standardization. Generally, modern analytical balances can determine mass values to ± 0.2 mg with ease and balances are available that can obtain mass values to ± 0.02 mg. In general, mass measurements are not the limiting factor. However, inadequate corrosion product removal or overcleaning will affect precision.

10.2 The determination of specimen area is usually the least precise step in corrosion rate determinations. The precision of calipers and other length measuring devices can vary widely. However, it generally is not necessary to achieve better than ± 1 % for area measurements for corrosion rate purposes.

10.3 The exposure time can usually be controlled to better than ± 1 % in most laboratory procedures. However, in field exposures, corrosive conditions can vary significantly and the estimation of how long corrosive conditions existed can present significant opportunities for error. Furthermore, corrosion processes are not necessarily linear with time, so that rate values may not be predictive of the future deterioration, but only are indications of the past exposure.

10.4 Regression analysis on results, as are shown in Fig. 1, can be used to obtain specific information on precision. See Guide G 16 for more information on statistical analysis.

10.5 Bias can result from inadequate corrosion product removal or metal removal caused by overcleaning. The use of repetitive cleaning steps, as shown in Fig. 1, can minimize both of these errors.

10.5.1 Corrosion penetration estimations based on mass loss can seriously underestimate the corrosion penetration caused by localized processes, such as pitting, cracking, crevice corrosion, and so forth.

11. Keywords

11.1 cleaning; corrosion product removal; evaluation; mass loss; metals; preparation; specimens

(Mandatory Information)
A1. CHEMICAL CLEANING PROCEDURES
TABLE A1.1 CHEMICAL CLEANING PROCEDURES FOR REMOVAL OF CORROSION PRODUCTS

Designation	Material	Solution	Time	Temperature	Remarks
C.1.1	Aluminum and Aluminum Alloys	50 mL phosphoric acid (H ₃ PO ₄ , sp gr 1.69) 20 g chromium trioxide (CrO ₃) Reagent water to make 1000 mL	5 to 10 min	90°C to Boiling	If corrosion product films remain, rinse, then follow with nitric acid procedure (C.1.2).
C.1.2		Nitric acid (HNO ₃ , sp gr 1.42)	1 to 5 min	20 to 25°C	Remove extraneous deposits and bulky corrosion products to avoid reactions that may result in excessive removal of base metal.
C.2.1	Copper and Copper Alloys	500 mL hydrochloric acid (HCl, sp gr 1.19) Reagent water to make 1000 mL	1 to 3 min	20 to 25°C	Deaeration of solution with purified nitrogen will minimize base metal removal.
C.2.2		4.9 g sodium cyanide (NaCN) Reagent water to make 1000 mL	1 to 3 min	20 to 25°C	Removes copper sulfide corrosion products that may not be removed by hydrochloric acid treatment (C.2.1).
C.2.3		100 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) Reagent water to make 1000 mL	1 to 3 min	20 to 25°C	Remove bulky corrosion products before treatment to minimize copper redeposition on specimen surface.
C.2.4		120 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) 30 g sodium dichromate (Na ₂ Cr ₂ O ₇ ·2H ₂ O) Reagent water to make 1000 mL	5 to 10 s	20 to 25°C	Removes redeposited copper resulting from sulfuric acid treatment.
C.2.5		54 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) Reagent water to make 1000 mL	30 to 60 min	40 to 50°C	Deaerate solution with nitrogen. Brushing of test specimens to remove corrosion products followed by re-immersion for 3 to 4 s is recommended.
C.3.1	Iron and Steel	1000 mL hydrochloric acid (HCl, sp gr 1.19) 20 g antimony trioxide (Sb ₂ O ₃) 50 g stannous chloride (SnCl ₂)	1 to 25 min	20 to 25°C	Solution should be vigorously stirred or specimen should be brushed. Longer times may be required in certain instances.
C.3.2		50 g sodium hydroxide (NaOH) 200 g granulated zinc or zinc chips Reagent water to make 1000 mL	30 to 40 min	80 to 90°C	Caution should be exercised in the use of any zinc dust since spontaneous ignition upon exposure to air can occur.
C.3.3		200 g sodium hydroxide (NaOH) 20 g granulated zinc or zinc chips Reagent water to make 1000 mL	30 to 40 min	80 to 90°C	Caution should be exercised in the use of any zinc dust since spontaneous ignition upon exposure to air can occur.
C.3.4		200 g diammonium citrate ((NH ₄) ₂ HC ₆ H ₅ O ₇) Reagent water to make 1000 mL	20 min	75 to 90°C	Depending upon the composition of the corrosion product, attack of base metal may occur.
C.3.5		500 mL hydrochloric acid (HCl, sp gr 1.19) 3.5 g hexamethylene tetramine Reagent water to make 1000 mL	10 min	20 to 25°C	Longer times may be required in certain instances.
C.3.6		Molten caustic soda (NaOH) with 1.5–2.0 % sodium hydride (NaH)	1 to 20 min	370°C	For details refer to Technical Information Bulletin SP29-370, "DuPont Sodium Hydride Descaling Process Operating Instructions."
C.4.1	Lead and Lead Alloys	10 mL acetic acid (CH ₃ COOH) Reagent water to make 1000 mL	5 min	Boiling	...
C.4.2		50 g ammonium acetate (CH ₃ COONH ₄) Reagent water to make 1000 mL	10 min	60 to 70°C	...
C.4.3		250 g ammonium acetate (CH ₃ COONH ₄) Reagent water to make 1000 mL	5 min	60 to 70°C	...
C.5.1	Magnesium and Magnesium Alloys	150 g chromium trioxide (CrO ₃) 10 g silver chromate (Ag ₂ CrO ₄) Reagent water to make 1000 mL	1 min	Boiling	The silver salt is present to precipitate chloride.
C.5.2		200 g chromium trioxide (CrO ₃) 10 g silver nitrate (AgNO ₃) 20 g barium nitrate (Ba(NO ₃) ₂) Reagent water to make 1000 mL	1 min	20 to 25°C	The barium salt is present to precipitate sulfate.
C.6.1	Nickel and Nickel Alloys	150 mL hydrochloric acid (HCl, sp gr 1.19) Reagent water to make 1000 mL	1 to 3 min	20 to 25°C	...
C.6.2		100 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) Reagent water to make 1000 mL	1 to 3 min	20 to 25°C	...
C.7.1	Stainless Steels	100 mL nitric acid (HNO ₃ , sp gr 1.42) Reagent water to make 1000 mL	20 min	60°C	...

TABLE A1.1 *Continued*

Designation	Material	Solution	Time	Temperature	Remarks
C.7.2		150 g diammonium citrate ($(\text{NH}_4)_2\text{HC}_6\text{H}_5\text{O}_7$) Reagent water to make 1000 mL	10 to 60 min	70°C	...
C.7.3		100 g citric acid ($\text{C}_6\text{H}_8\text{O}_7$) 50 mL sulfuric acid (H_2SO_4 , sp gr 1.84) 2 g inhibitor (diorthotolyl thiourea or quinoline ethyliodide or betanaphthol quinoline) Reagent water to make 1000 mL	5 min	60°C	...
C.7.4		200 g sodium hydroxide (NaOH) 30 g potassium permanganate (KMnO_4) Reagent water to make 1000 mL <i>followed by</i> 100 g diammonium citrate ($(\text{NH}_4)_2\text{HC}_6\text{H}_5\text{O}_7$) Reagent water to make 1000 mL	5 min	Boiling	...
C.7.5		100 mL nitric acid (HNO_3 , sp gr 1.42) 20 mL hydrofluoric acid (HF, sp gr 1.198–48 %) Reagent water to make 1000 mL	5 to 20 min	20 to 25°C	...
C.7.6		200 g sodium hydroxide (NaOH) 50 g zinc powder Reagent water to make 1000 mL	20 min	Boiling	Caution should be exercised in the use of any zinc dust since spontaneous ignition upon exposure to air can occur.
C.8.1	Tin and Tin Alloys	150 g trisodium phosphate ($\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$) Reagent water to make 1000 mL	10 min	Boiling	...
C.8.2		50 mL hydrochloric acid (HCl, sp gr 1.19) Reagent water to make 1000 mL	10 min	20°C	...
C.9.1	Zinc and Zinc Alloys	150 mL ammonium hydroxide (NH_4OH , sp gr 0.90) Reagent water to make 1000 mL <i>followed by</i> 50 g chromium trioxide (CrO_3) 10 g silver nitrate (AgNO_3) Reagent water to make 1000 mL	5 min 15 to 20 s	20 to 25°C Boiling	... The silver nitrate should be dissolved in water and added to the boiling chromic acid to prevent excessive crystallization of silver chromate. The chromic acid must be sulfate free to avoid attack of the zinc base metal.
C.9.2		100 g ammonium chloride (NH_4Cl) Reagent water to make 1000 mL	2 to 5 min	70°C	...
C.9.3		200 g chromium trioxide (CrO_3) Reagent water to make 1000 mL	1 min	80°C	Chloride contamination of the chromic acid from corrosion products formed in salt environments should be avoided to prevent attack of the zinc base metal.
C.9.4		85 mL hydriodic acid (HI, sp gr 1.5) Reagent water to make 1000 mL	15 s	20 to 25°C	Some zinc base metal may be removed. A control specimen (3.1.1) should be employed.
C.9.5		100 g ammonium persulfate ($(\text{NH}_4)_2\text{S}_2\text{O}_8$) Reagent water to make 1000 mL	5 min	20 to 25°C	Particularly recommended for galvanized steel.
C.9.6		100 g ammonium acetate ($\text{CH}_3\text{COONH}_4$) Reagent water to make 1000 mL	2 to 5 min	70°C	...

A2. ELECTROLYTIC CLEANING PROCEDURES

TABLE A2.1 ELECTROLYTIC CLEANING PROCEDURES FOR REMOVAL OF CORROSION PRODUCTS

Designation	Material	Solution	Time	Temperature	Remarks
E.1.1	Iron, Cast Iron, Steel	75 g sodium hydroxide (NaOH) 25 g sodium sulfate (Na_2SO_4) 75 g sodium carbonate (Na_2CO_3) Reagent water to make 1000 mL	20 to 40 min	20 to 25°C	Cathodic treatment with 100 to 200 A/m ² cur- rent density. Use carbon, platinum or stainless steel anode.

TABLE A2.1 *Continued*

Designation	Material	Solution	Time	Temperature	Remarks
E.1.2		28 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) 0.5 g inhibitor (diorthotolyl thiourea or quinoline ethyliodide or betanaphthol quinoline) Reagent water to make 1000 mL	3 min	75°C	Cathodic treatment with 2000 A/m ² current density. Use carbon, platinum or lead anode.
E.1.3		100 g diammonium citrate ((NH ₄) ₂ HC ₆ H ₅ O ₇) Reagent water to make 1000 mL	5 min	20 to 25°C	Cathodic treatment with 100 A/m ² current density. Use carbon or platinum anode.
E.2.1	Lead and Lead Alloys	28 mL sulfuric acid (H ₂ SO ₄ , sp gr 1.84) 0.5 g inhibitor (diorthotolyl thiourea or quinoline ethyliodide or betanaphthol quinoline) Reagent water to make 1000 mL	3 min	75°C	Cathodic treatment with 2000 A/m ² current density. Use carbon, platinum or lead anode.
E.3.1	Copper and Copper Alloys	7.5 g potassium chloride (KCl) Reagent water to make 1000 mL	1 to 3	20 to 25°C	Cathodic treatment with 100 A/m ² current density. Use carbon or platinum anode.
E.4.1	Zinc and Cadmium	50 g dibasic sodium phosphate (Na ₂ HPO ₄) Reagent water to make 1000 mL	5 min	70°C	Cathodic treatment with 110 A/m ² current density. Specimen must be energized prior to immersion. Use carbon, platinum or stainless steel anode.
E.4.2		100 g sodium hydroxide (NaOH) Reagent water to make 1000 mL	1 to 2 min	20 to 25°C	Cathodic treatment with 100 A/m ² current density. Specimen must be energized prior to immersion. Use carbon, platinum or stainless steel anode.
E.5.1	General (excluding Aluminum, Magnesium and Tin Alloys)	20 g sodium hydroxide (NaOH) Reagent water to make 1000 mL	5 to 10 min	20 to 25°C	Cathodic treatment with 300 A/m ² current density. A S31600 stainless steel anode may be used.

APPENDIXES

(Nonmandatory Information)

X1. DENSITIES FOR A VARIETY OF METALS AND ALLOYS

TABLE X1.1 DENSITIES FOR A VARIETY OF METALS AND ALLOYS

NOTE 1—All UNS numbers that include the letter X indicate a series of numbers under one category.

NOTE 2—An asterisk indicates that a UNS number not available.

Aluminum Alloys		
UNS Number	Alloy	Density g/cm ³
A91100	1100	2.71
A91199	1199	2.70
A92024	2024	2.78
A92219	2219	2.84
A93003	3003	2.73
A93004	3004	2.72
A95005	5005	2.70
A95050	5050	2.69
A95052	5052	2.68
A95083	5083	2.66
A95086	5086	2.66
A95154	5154	2.66
A95357	5357	2.69
A95454	5454	2.69
A95456	5456	2.66
A96061	6061	2.70
*	6062	2.70
A96070	6070	2.71
A96101	6101	2.70
A97075	7075	2.81
A97079	7079	2.75
A97178	7178	2.83
Stainless Steels		
S20100	Type 201	7.94
S20200	Type 202	7.94
S30200	Type 302	7.94
S30400	Type 304	7.94

TABLE X1.1 *Continued*

Aluminum Alloys		
UNS Number	Alloy	Density g/cm ³
S30403	Type 304L	7.94
S30900	Type 309	7.98
S31000	Type 310	7.98
S31100	Type 311	7.98
S31600	Type 316	7.98
S31603	Type 316L	7.98
S31700	Type 317	7.98
S32100	Type 321	7.94
S32900	Type 329	7.98
N08330	Type 330	7.98
S34700	Type 347	8.03
S41000	Type 410	7.70
S43000	Type 430	7.72
S44600	Type 446	7.65
S50200	Type 502	7.82
Other Ferrous Metals		
F1XXXX	Gray cast iron	7.20
GXXXXX–KXXXXX	Carbon steel	7.86
*	Silicon iron	7.00
KXXXXX	Low alloy steels	7.85
Copper Alloys		
C38600	Copper	8.94
C23000	Red brass 230	8.75
C26000	Cartridge brass 260	8.52
C28000	Muntz metal 280	8.39
*	Admiralty 442	8.52
C44300	Admiralty 443	8.52
C44400	Admiralty 444	8.52
C44500	Admiralty 445	8.52
C68700	Aluminum brass 687	8.33
C22000	Commercial bronze 220	8.80
C60800	Aluminum bronze, 5 % 608	8.16
*	Aluminum bronze, 8 % 612	7.78
*	Composition M	8.45
*	Composition G	8.77
C51000	Phosphor bronze, 5 % 510	8.86
C52400	Phosphor bronze, 10 % 524	8.77
*	85-5-5-5	8.80
C65500	Silicon bronze 655	8.52
C70600	Copper nickel 706	8.94
C71000	Copper nickel 710	8.94
C71500	Copper nickel 715	8.94
C75200	Nickel silver 752	8.75
Lead		
L53305–53405	Antimonial	10.80
L5XXXX	Chemical	11.33
Nickel Alloys		
N02200	Nickel 200	8.89
N04400	Nickel copper 400	8.84
N06600	Nickel chromium iron alloy 600	8.51
N06625	Nickel chromium molybdenum alloy 625	8.44
N08825	Iron nickel chromium alloy 825	8.14
N08020	Iron nickel chromium alloy 20 Cb-3	8.08
*	Iron nickel chromium cast alloy 20	8.02
N10665	Nickel molybdenum alloy B2	9.2
N10276	Nickel chromium molybdenum alloy C-276	8.8
N06985	Nickel chromium molybdenum alloy G-3	8.3
Other Metals		
M1XXXX	Magnesium	1.74
R03600	Molybdenum	10.22
P04980	Platinum	21.45
P07016	Silver	10.49
R05200	Tantalum	16.60
L13002	Tin	7.30
R50250	Titanium	4.54
Z13001	Zinc	7.13
R60001	Zirconium	6.53

X2. CALCULATION OF AVERAGE THICKNESS LOSS RATE OF AN ALLOY WHEN THE DENSITY OF THE CORRODING METAL DIFFERS FROM THAT OF THE BULK ALLOY

X2.1 Example

X2.1.1 55% Al-Zn alloy coating on steel sheet exposed for 20.95 years at Point Reyes, CA. (As reported in H.E. Townsend and H.H.Lawson, “Twenty-One Year Results for Metallic-Coated Sheet in the ASTM 1976 Atmospheric Corrosion Tests”).⁸

X2.2 Measurements

X2.2.1 Initial aluminum content of coating, C_1 , as measured by stripping (Table A1.1, C.3.) and chemical analysis of uncorroded specimens.

$$C_1 = 55.0\% \text{ Al} \quad (\text{X2.1})$$

X2.2.2 Time of Exposure, T

$$T = 20.95 \text{ years} = 183\,648 \text{ hours} \quad (\text{X2.2})$$

X2.2.3 Specimen Area, A

$$A = 300 \text{ cm}^2 \quad (\text{X2.3})$$

X2.2.4 Initial Mass, W_1

$$W_1 = 79.3586 \text{ g} \quad (\text{X2.4})$$

X2.2.5 Mass after exposure and removal of corrosion products according to Table A1.1, C.9.3, W_2

$$W_2 = 78.7660 \text{ g} \quad (\text{X2.5})$$

X2.2.6 Mass after removal of remaining coating according to Table A1.1, C.3.5, W_3

$$W_3 = 75.0810 \text{ g} \quad (\text{X2.6})$$

X2.2.7 Aluminum content of remaining uncorroded coating by chemical analysis of the stripping solution, C_u

$$C_u = 57.7\% \text{ Al} \quad (\text{X2.7})$$

X2.3 Calculations

X2.3.1 Mass loss of corroded coating, W

$$W = W_1 - W_2 = 79.3586 - 78.7660 = 0.5926 \text{ g} \quad (\text{X2.8})$$

X2.3.2 Mass of remaining uncorroded coating, W_u

$$W_u = W_2 - W_3 = 78.7660 - 75.0810 = 3.6850 \text{ g} \quad (\text{X2.9})$$

X2.3.3 Total mass of original coating, W_t

$$W_t = W + W_u = 0.5926 + 3.6850 = 4.2776 \text{ g} \quad (\text{X2.10})$$

X2.3.4 Composition of corroded coating, C

$$CW + C_u W_u = C_1 W_t \quad (\text{X2.11})$$

Rearranging gives

$$C = (C_1 W_t - C_u W_u) / W \quad (\text{X2.12})$$

$$C = (55.0 \times 4.2776 - 57.7 \times 3.6850) / 0.5926 \quad (\text{X2.13})$$

$$C = 38.2\% \text{ Al} \quad (\text{X2.14})$$

X2.3.5 The density, D , of a 38.2 % Al-Zn alloy is 4.32 g/cm³. In cases where alloy densities are not known, they can be estimated by linear interpolation of the component densities.

X2.3.6 Calculate the average thickness loss rate, L (corrosion rate per Eq 1).

$$L = (K \times W) / (A \times T \times D) \quad (\text{X2.15})$$

where K is given in 8.1.2 as 8.76×10^7

$$L = (8.76 \times 10^7 \times 0.5926) / (300 \times 183\,648 \times 4.32)$$

$$L = 0.218 \text{ micrometres per year}$$

⁸ Outdoor Atmospheric Corrosion, STP 1421, H. E. Townsend, Ed., American Society for Testing and Materials, West Conshohocken, PA, 2002, pp. 284–291.

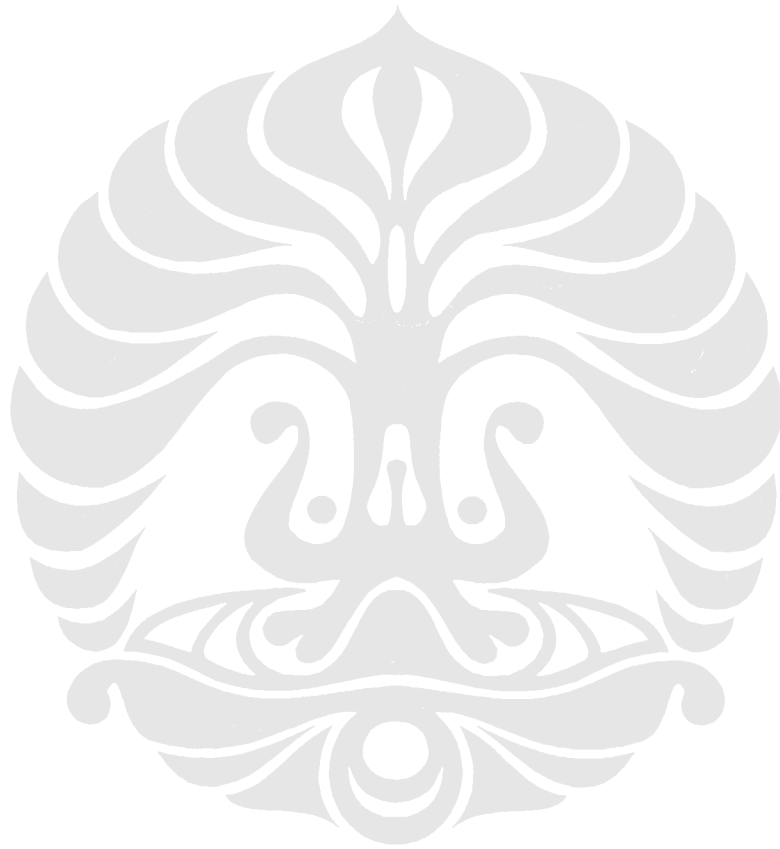
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LAMPIRAN III

HASIL UJI KOMPOSISI





Department of Metallurgy and Materials Engineering
UNIVERSITY OF INDONESIA

CHEMICAL COMPOSITION TEST REPORT

Contract No. / No. Kontrak - : 710

Standards / Standar : ASTM A751

Customer / Pemberi Kerja : CMPFA-Pak Johny Team

Materials / Material : T5 SRK
(Baja Y)

	Fe	C	Si	Mn	P	S	Cr	Mo
1	99.550	0.0562	< 0.0050	0.202	0.0091	0.0108	0.0148	< 0.0050
2	99.541	0.0536	0.0051	0.200	0.0088	0.0100	0.0144	< 0.0050
3	99.562	0.0483	0.0061	0.197	0.0073	0.0082	0.0148	< 0.0050
Ave	99.551	0.0527	< 0.0050	0.200	0.0084	0.0097	0.0146	< 0.0050

	Ni	Al	Co	Cu	Nb	Ti	V	W
1	< 0.0050	0.0372	0.0047	0.0090	< 0.0020	< 0.0020	0.0023	< 0.0150
2	< 0.0050	0.0394	0.0047	0.0109	< 0.0020	< 0.0020	0.0023	< 0.0150
3	< 0.0050	0.0378	0.0042	0.0096	< 0.0020	< 0.0020	0.0022	< 0.0150
Ave	< 0.0050	0.0382	0.0046	0.0098	< 0.0020	< 0.0020	0.0023	< 0.0150

	Pb	Sn	B	Ca	Zr	As	Bi
1	< 0.0250	< 0.0020	< 0.0010	> 0.0010	< 0.0020	< 0.0050	0.0921
2	< 0.0250	< 0.0020	< 0.0010	> 0.0010	0.0059	0.0073	0.0886
3	< 0.0250	< 0.0020	< 0.0010	> 0.0010	0.0055	< 0.0050	0.0893
Ave	< 0.0250	< 0.0020	< 0.0010	> 0.0010	0.0044	0.0055	0.0900

Datum / date

9/20/2007

Tested by / Diuji oleh :

Dhibas

Approved by / Disetujui oleh :

Deny/Jaya

Center of Materials Processing and Failure Analysis
Dept. of Metallurgy and Material Engineering
Gedung Metalurgi dan Material FTUI
Kampus Baru Universitas Indonesia
Depok - West Java INDONESIA 16424
Tel. : +62 21 7863510 Fax: +62 21 7872350
Web: www.metal.ui.ac.id
e-mail: cmpfa@metal.ui.ac.id



Department of Metallurgy and Materials Engineering
UNIVERSITY OF INDONESIA

CHEMICAL COMPOSITION TEST REPORT

Contract No. / No. Kontrak - : 710

Standards / Standar : ASTM A751

Customer / Pemberi Kerja : CMPFA-Pak Johny Team

Materials / Material : T3 SRK
(Baja X)

	Fe	C	Si	Mn	P	S	Cr	Mo
1	98.732	0.0597	< 0.0050	0.202	0.0167	0.0128	0.210	0.0062
2	98.747	0.0588	< 0.0050	0.201	0.0194	0.0150	0.210	0.0051
3	98.788	0.0503	< 0.0050	0.202	0.0165	0.0145	0.206	0.0054
Ave	98.756	0.0563	< 0.0050	0.202	0.0175	0.0141	0.209	0.0056

	Ni	Al	Co	Cu	Nb	Ti	V	W
1	0.543	0.0335	0.0322	0.0740	< 0.0020	< 0.0020	0.0042	< 0.0150
2	0.548	0.0330	0.0325	0.0747	< 0.0020	< 0.0020	0.0033	< 0.0150
3	0.539	0.0327	0.0314	0.0668	< 0.0020	< 0.0020	0.0043	< 0.0150
Ave	0.544	0.0330	0.0320	0.0718	< 0.0020	< 0.0020	0.0039	< 0.0150

	Pb	Sn	B	Ca	Zr	As	Bi
1	< 0.0250	0.0033	< 0.0010	0.0005	0.0074	0.0055	0.0374
2	< 0.0250	0.0040	< 0.0010	0.0005	0.0065	0.0078	< 0.0300
3	< 0.0250	0.0027	< 0.0010	0.0004	0.0065	0.0059	< 0.0300
Ave	< 0.0250	0.0034	< 0.0010	0.0005	0.0068	0.0064	< 0.0300

Datum / date

9/20/2007

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Center of Materials Processing and Failure Analysis
Dept. of Metallurgy and Material Engineering
Gedung Metalurgi dan Material FTUI
Kampus Baru Universitas Indonesia
Depok - West Java INDONESIA 16424
Tel. : +62 21 7863510 Fax: +62 21 7872350
Web: www.metal.ui.ac.id
e-mail: cmpfa@metal.ui.ac.id

LAMPIRAN IV

HASIL UJI TARIK



BAJA X

Arah Rol 0°

L = 50 mm

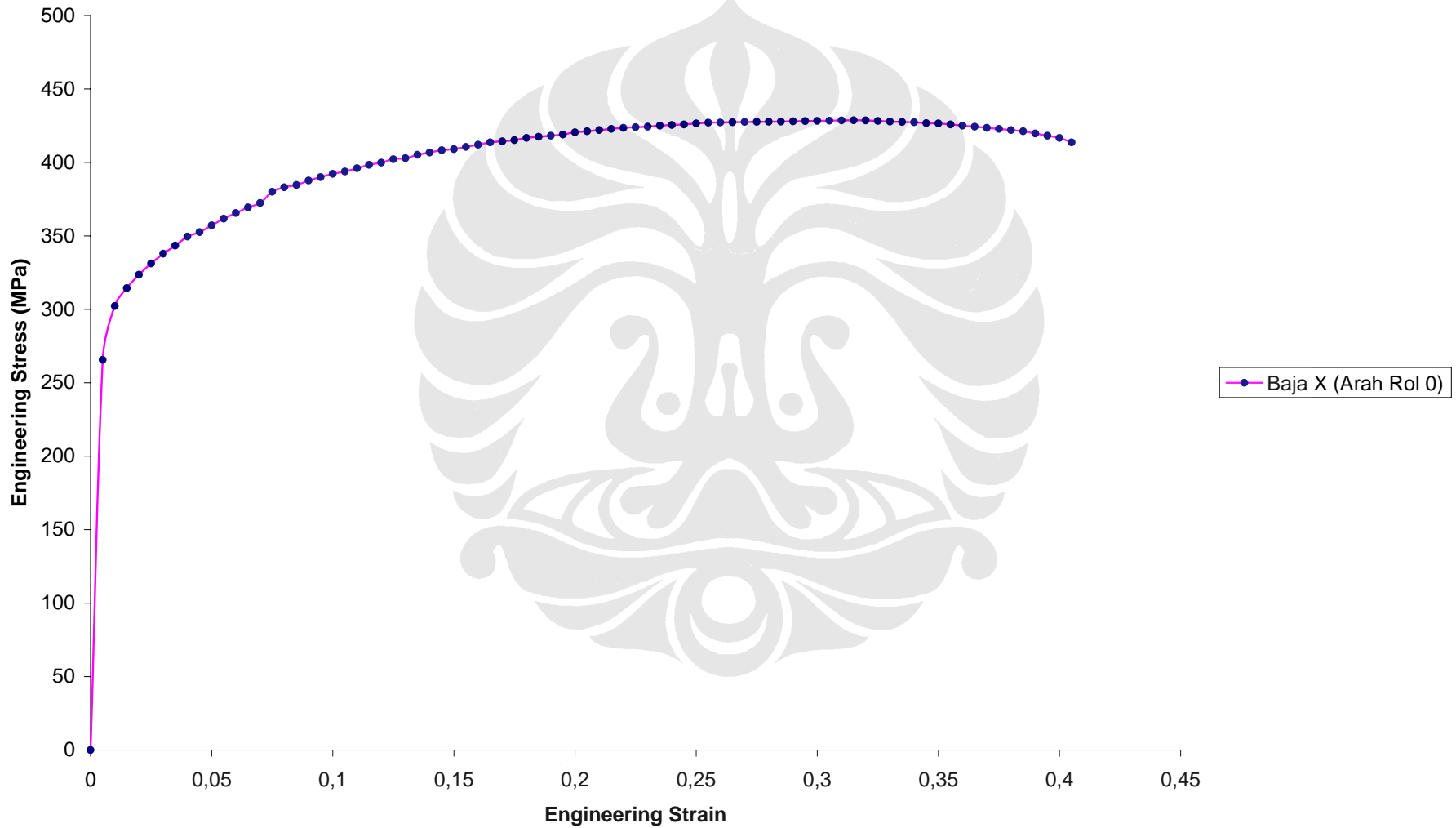
A0 = 12,85 mm²

No.	dl (mm)	P (Kg)	Strain	Stress (Kg/mm ²)	T. Stress	T. Strain	Stress (MPa)	T. Stress (MPa)
1	0	0	0	0	0	0	0	0
2	0,25	348	0,005	27,08171206	27,21712062	0,004987542	265,5632685	266,8910848
3	0,5	396	0,01	30,81712062	31,12529183	0,009950331	302,1926848	305,2146117
4	0,75	412	0,015	32,06225681	32,54319066	0,014888612	314,4024903	319,1185276
5	1	424	0,02	32,99610895	33,65603113	0,019802627	323,5598444	330,0310412
6	1,25	434	0,025	33,77431907	34,61867704	0,024692613	331,1909728	339,4707471
7	1,5	442,8	0,03	34,45914397	35,49291829	0,029558802	337,9063658	348,0435567
8	1,75	450	0,035	35,01945525	36,24513619	0,034401427	343,4007782	355,4198054
9	2	458	0,04	35,64202335	37,06770428	0,039220713	349,5056809	363,4859082
10	2,25	462	0,045	35,95330739	37,57120623	0,044016885	352,5581323	368,4232482
11	2,5	468	0,05	36,42023346	38,24124514	0,048790164	357,1368093	374,9936498
12	2,75	474	0,055	36,88715953	38,91595331	0,053540767	361,7154864	381,6098381
13	3	479	0,06	37,27626459	39,51284047	0,058268908	365,5310506	387,4629136
14	3,25	484	0,065	37,66536965	40,11361868	0,062974799	369,3466148	393,3541447
15	3,5	488	0,07	37,9766537	40,63501946	0,067658648	372,3990661	398,4670008
16	3,75	498	0,075	38,75486381	41,6614786	0,072320662	380,0301946	408,5324591
17	4	502	0,08	39,06614786	42,19143969	0,076961041	383,0826459	413,7292576
18	4,25	504	0,085	39,22178988	42,55564202	0,081579987	384,6088716	417,3006257
19	4,5	508	0,09	39,53307393	43,09105058	0,086177696	387,661323	422,550842
20	4,75	511	0,095	39,76653696	43,54435798	0,090754363	389,9506615	426,9959743
21	5	514	0,1	40	44	0,09531018	392,24	431,464
22	5,25	516	0,105	40,15564202	44,37198444	0,099845335	393,7662257	435,1116794
23	5,5	519	0,11	40,38910506	44,83190661	0,104360015	396,0555642	439,6216763
24	5,75	522	0,115	40,62256809	45,29416342	0,108854405	398,3449027	444,1545665
25	6	524	0,12	40,77821012	45,67159533	0,113328685	399,8711284	447,8556638

26	6,25	527	0,125	41,01167315	46,1381323	0,117783036	402,1604669	452,4305253
27	6,5	528	0,13	41,08949416	46,4311284	0,122217633	402,9235798	455,3036451
28	6,75	531	0,135	41,3229572	46,90155642	0,126632651	405,2129183	459,9166623
29	7	533	0,14	41,47859922	47,28560311	0,131028262	406,739144	463,6826241
30	7,25	535	0,145	41,63424125	47,67120623	0,135404637	408,2653696	467,4638482
31	7,5	536	0,15	41,71206226	47,9688716	0,139761942	409,0284825	470,3827549
32	7,75	538	0,155	41,86770428	48,35719844	0,144100344	410,5547082	474,1906879
33	8	540	0,16	42,0233463	48,74708171	0,148420005	412,0809339	478,0138833
34	8,25	542	0,165	42,17898833	49,1385214	0,152721087	413,6071595	481,8523409
35	8,5	543	0,17	42,25680934	49,44046693	0,157003749	414,3702724	484,8132187
36	8,75	544	0,175	42,33463035	49,74319066	0,161268148	415,1333852	487,7817276
37	9	546	0,18	42,49027237	50,1385214	0,165514438	416,6596109	491,6583409
38	9,25	547	0,185	42,56809339	50,44319066	0,169742775	417,4227237	494,6459276
39	9,5	548	0,19	42,6459144	50,74863813	0,173953307	418,1858366	497,6411455
40	9,75	549	0,195	42,72373541	51,05486381	0,178146185	418,9489494	500,6439946
41	10	551	0,2	42,87937743	51,45525292	0,182321557	420,4751751	504,5702101
42	10,25	552	0,205	42,95719844	51,76342412	0,186479567	421,2382879	507,592137
43	10,5	553	0,21	43,03501946	52,07237354	0,19062036	422,0014008	510,6216949
44	10,75	554	0,215	43,11284047	52,38210117	0,194744077	422,7645136	513,658884
45	11	555	0,22	43,19066148	52,692607	0,198850859	423,5276265	516,7037043
46	11,25	555,6	0,225	43,23735409	52,96575875	0,202940844	423,9854942	519,3822304
47	11,5	556	0,23	43,26848249	53,22023346	0,207014169	424,2907393	521,8776093
48	11,75	557	0,235	43,3463035	53,53268482	0,21107097	425,0538521	524,9415074
49	12	557,6	0,24	43,39299611	53,80731518	0,21511138	425,5117198	527,6345326
50	12,25	558	0,245	43,42412451	54,06303502	0,21913553	425,816965	530,1421214
51	12,5	559	0,25	43,50194553	54,37743191	0,223143551	426,5800778	533,2250973
52	12,75	559,6	0,255	43,54863813	54,65354086	0,227135573	427,0379455	535,9326216
53	13	559,8	0,26	43,56420233	54,89089494	0,231111721	427,1905681	538,2601158
54	13,25	560	0,265	43,57976654	55,12840467	0,235072122	427,3431907	540,5891362
55	13,5	560,2	0,27	43,59533074	55,36607004	0,2390169	427,4958132	542,9196828
56	13,75	560,4	0,275	43,61089494	55,60389105	0,242946179	427,6484358	545,2517556

57	14	560,5	0,28	43,61867704	55,83190661	0,246860078	427,7247471	547,4876763
58	14,25	560,6	0,285	43,62645914	56,06	0,250758718	427,8010584	549,72436
59	14,5	560,8	0,29	43,64202335	56,29821012	0,254642218	427,9536809	552,0602484
60	14,75	561	0,295	43,65758755	56,53657588	0,258510695	428,1063035	554,397663
61	15	561,2	0,3	43,67315175	56,77509728	0,262364264	428,2589261	556,7366039
62	15,25	561,4	0,305	43,68871595	57,01377432	0,266203041	428,4115486	559,077071
63	15,5	561,6	0,31	43,70428016	57,252607	0,270027137	428,5641712	561,4190643
64	15,75	561,8	0,315	43,71984436	57,49159533	0,273836666	428,7167938	563,7625838
65	16	561,6	0,32	43,70428016	57,68964981	0,277631737	428,5641712	565,704706
66	16,25	561,2	0,325	43,67315175	57,86692607	0,281412459	428,2589261	567,443077
67	16,5	560,6	0,33	43,62645914	58,02319066	0,285178942	427,8010584	568,9754076
68	16,75	560,2	0,335	43,59533074	58,19976654	0,288931292	427,4958132	570,7069107
69	17	560	0,34	43,57976654	58,39688716	0,292669614	427,3431907	572,6398755
70	17,25	559,2	0,345	43,51750973	58,53105058	0,296394013	426,7327004	573,955482
71	17,5	559	0,35	43,50194553	58,72762646	0,300104592	426,5800778	575,8831051
72	17,75	558	0,355	43,42412451	58,83968872	0,303801454	425,816965	576,9819875
73	18	557	0,36	43,3463035	58,95097276	0,3074847	425,0538521	578,0732389
74	18,25	556	0,365	43,26848249	59,0614786	0,311154429	424,2907393	579,1568591
75	18,5	555	0,37	43,19066148	59,17120623	0,31481074	423,5276265	580,2328482
76	18,75	554	0,375	43,11284047	59,28015564	0,318453731	422,7645136	581,3012062
77	19	553	0,38	43,03501946	59,38832685	0,322083499	422,0014008	582,3619331
78	19,25	552	0,385	42,95719844	59,49571984	0,32570014	421,2382879	583,4150288
79	19,5	550	0,39	42,80155642	59,49416342	0,329303747	419,7120623	583,3997665
80	19,75	548	0,395	42,6459144	59,49105058	0,332894415	418,1858366	583,369242
81	20	546	0,4	42,49027237	59,48638132	0,336472237	416,6596109	583,3234553
82	20,25	542	0,405	42,17898833	59,2614786	0,340037303	413,6071595	581,1180591

Engineering Stress vs Engineering Strain



BAJA X

Arah Rol 90°

L = 50 mm

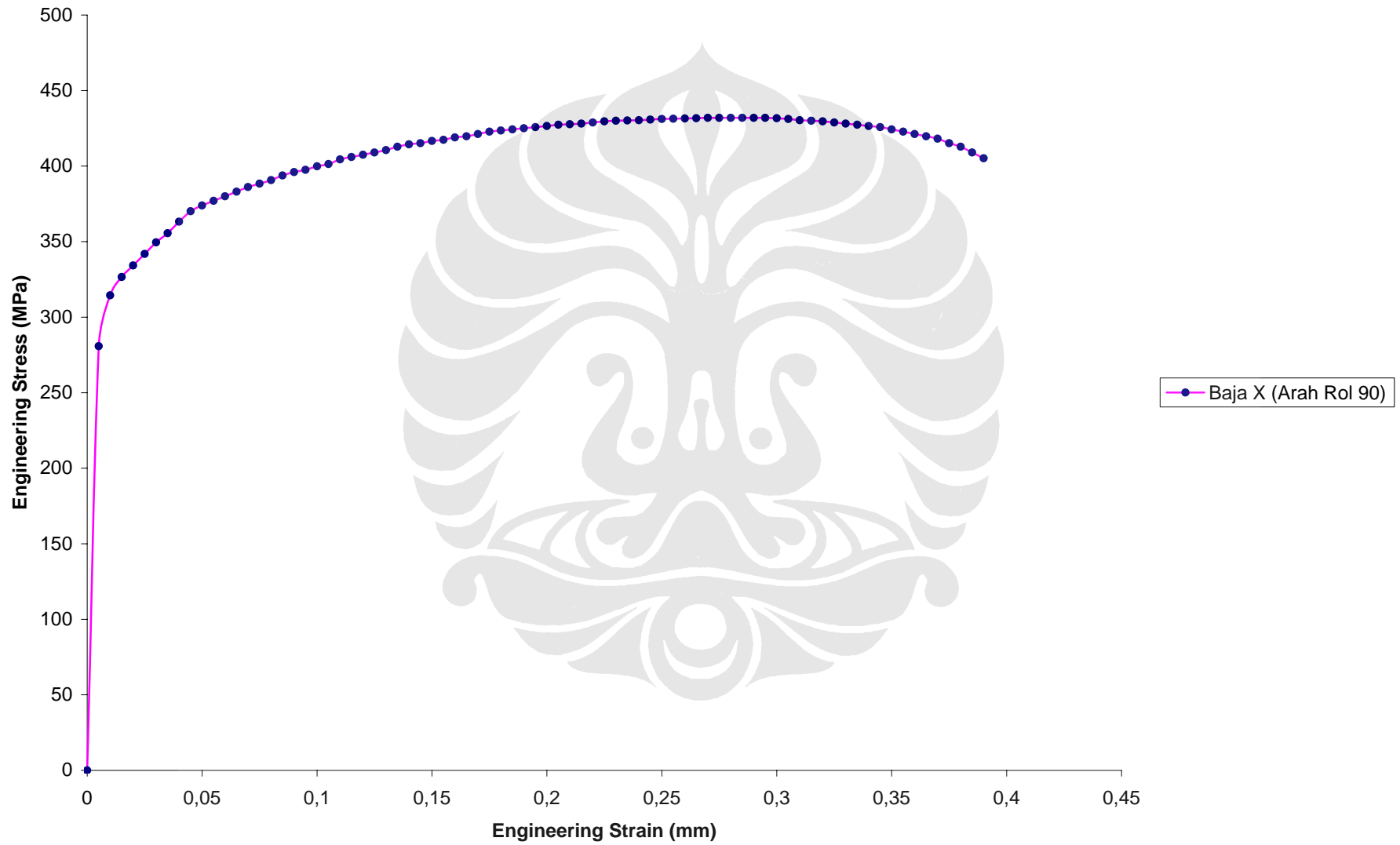
Ao = 12,85 mm²

No.	dl (mm)	P (Kg)	Strain (dl/Lo)	P/Ao (Kg/mm ²)	T. Stress	T. Strain	Stress (MPa)	T. Stress (MPa)
1	0	0	0	0	0	0	0	0
2	0,25	368	0,005	28,6381323	28,78132296	0,004987542	280,8255253	282,2296529
3	0,5	412	0,01	32,06225681	32,38287938	0,009950331	314,4024903	317,5465152
4	0,75	428	0,015	33,307393	33,80700389	0,014888612	326,6122957	331,5114802
5	1	438	0,02	34,08560311	34,76731518	0,019802627	334,2434241	340,9282926
6	1,25	448	0,025	34,86381323	35,73540856	0,024692613	341,8745525	350,4214163
7	1,5	458	0,03	35,64202335	36,71128405	0,029558802	349,5056809	359,9908514
8	1,75	466	0,035	36,26459144	37,53385214	0,034401427	355,6105837	368,0569541
9	2	476	0,04	37,04280156	38,52451362	0,039220713	363,2417121	377,7713805
10	2,25	485	0,045	37,74319066	39,44163424	0,044016885	370,1097276	386,7646654
11	2,5	490	0,05	38,13229572	40,03891051	0,048790164	373,9252918	392,6215564
12	2,75	494	0,055	38,44357977	40,55797665	0,053540767	376,9777432	397,7115191
13	3	498	0,06	38,75486381	41,08015564	0,058268908	380,0301946	402,8320062
14	3,25	502	0,065	39,06614786	41,60544747	0,062974799	383,0826459	407,9830179
15	3,5	506	0,07	39,37743191	42,13385214	0,067658648	386,1350973	413,1645541
16	3,75	509	0,075	39,61089494	42,58171206	0,072320662	388,4244358	417,5562685
17	4	512	0,08	39,84435798	43,03190661	0,076961041	390,7137743	421,9708763
18	4,25	516	0,085	40,15564202	43,5688716	0,081579987	393,7662257	427,2363549
19	4,5	519	0,09	40,38910506	44,02412451	0,086177696	396,0555642	431,700565
20	4,75	521	0,095	40,54474708	44,39649805	0,090754363	397,5817899	435,3520599
21	5	524	0,1	40,77821012	44,85603113	0,09531018	399,8711284	439,8582412
22	5,25	526	0,105	40,93385214	45,23190661	0,099845335	401,3973541	443,5440763
23	5,5	530	0,11	41,24513619	45,78210117	0,104360015	404,4498054	448,939284
24	5,75	532	0,115	41,40077821	46,1618677	0,108854405	405,9760311	452,6632747

25	6	534	0,12	41,55642023	46,54319066	0,113328685	407,5022568	456,4025276
26	6,25	536	0,125	41,71206226	46,92607004	0,117783036	409,0284825	460,1570428
27	6,5	538	0,13	41,86770428	47,31050584	0,122217633	410,5547082	463,9268202
28	6,75	541	0,135	42,10116732	47,7848249	0,126632651	412,8440467	468,577993
29	7	543	0,14	42,25680934	48,17276265	0,131028262	414,3702724	472,3821105
30	7,25	544	0,145	42,33463035	48,47315175	0,135404637	415,1333852	475,3277261
31	7,5	546	0,15	42,49027237	48,86381323	0,139761942	416,6596109	479,1585525
32	7,75	547	0,155	42,56809339	49,16614786	0,144100344	417,4227237	482,1232459
33	8	549	0,16	42,72373541	49,55953307	0,148420005	418,9489494	485,9807813
34	8,25	550	0,165	42,80155642	49,86381323	0,152721087	419,7120623	488,9645525
35	8,5	552	0,17	42,95719844	50,25992218	0,157003749	421,2382879	492,8487969
36	8,75	554	0,175	43,11284047	50,65758755	0,161268148	422,7645136	496,7483035
37	9	555	0,18	43,19066148	50,96498054	0,165514438	423,5276265	499,7625992
38	9,25	556	0,185	43,26848249	51,27315175	0,169742775	424,2907393	502,7845261
39	9,5	557	0,19	43,3463035	51,58210117	0,173953307	425,0538521	505,814084
40	9,75	558	0,195	43,42412451	51,89182879	0,178146185	425,816965	508,8512732
41	10	559	0,2	43,50194553	52,20233463	0,182321557	426,5800778	511,8960934
42	10,25	560	0,205	43,57976654	52,51361868	0,186479567	427,3431907	514,9485447
43	10,5	560,5	0,21	43,61867704	52,77859922	0,19062036	427,7247471	517,546944
44	10,75	561	0,215	43,65758755	53,04396887	0,194744077	428,1063035	520,1491588
45	11	562	0,22	43,73540856	53,35719844	0,198850859	428,8694163	523,2206879
46	11,25	563	0,225	43,81322957	53,67120623	0,202940844	429,6325292	526,2998482
47	11,5	563,5	0,23	43,85214008	53,9381323	0,207014169	430,0140856	528,9173253
48	11,75	563,75	0,235	43,87159533	54,18142023	0,21107097	430,2048638	531,3030068
49	12	564	0,24	43,89105058	54,42490272	0,21511138	430,395642	533,6905961
50	12,25	564,5	0,245	43,92996109	54,69280156	0,21913553	430,7771984	536,3176121
51	12,5	565	0,25	43,9688716	54,96108949	0,223143551	431,1587549	538,9484436
52	12,75	565,25	0,255	43,98832685	55,20535019	0,227135573	431,3495331	541,343664
53	13	565,5	0,26	44,0077821	55,44980545	0,231111721	431,5403113	543,7407922
54	13,25	565,75	0,265	44,02723735	55,69445525	0,235072122	431,7310895	546,1398282
55	13,5	566	0,27	44,04669261	55,93929961	0,2390169	431,9218677	548,540772

56	13,75	566	0,275	44,04669261	56,15953307	0,242946179	431,9218677	550,7003813
57	14	566	0,28	44,04669261	56,37976654	0,246860078	431,9218677	552,8599907
58	14,25	566	0,285	44,04669261	56,6	0,250758718	431,9218677	555,0196
59	14,5	566	0,29	44,04669261	56,82023346	0,254642218	431,9218677	557,1792093
60	14,75	566	0,295	44,04669261	57,04046693	0,258510695	431,9218677	559,3388187
61	15	565,75	0,3	44,02723735	57,23540856	0,262364264	431,7310895	561,2504163
62	15,25	565	0,305	43,9688716	57,37937743	0,266203041	431,1587549	562,6621751
63	15,5	564	0,31	43,89105058	57,49727626	0,270027137	430,395642	563,8182911
64	15,75	563,5	0,315	43,85214008	57,6655642	0,273836666	430,0140856	565,4685226
65	16	563	0,32	43,81322957	57,83346304	0,277631737	429,6325292	567,1149385
66	16,25	562	0,325	43,73540856	57,94941634	0,281412459	428,8694163	568,2519767
67	16,5	561	0,33	43,65758755	58,06459144	0,285178942	428,1063035	569,3813837
68	16,75	560	0,335	43,57976654	58,17898833	0,288931292	427,3431907	570,5031595
69	17	559	0,34	43,50194553	58,292607	0,292669614	426,5800778	571,6173043
70	17,25	558	0,345	43,42412451	58,40544747	0,296394013	425,816965	572,7238179
71	17,5	556	0,35	43,26848249	58,41245136	0,300104592	424,2907393	572,7924981
72	17,75	554	0,355	43,11284047	58,41789883	0,303801454	422,7645136	572,845916
73	18	552	0,36	42,95719844	58,42178988	0,3074847	421,2382879	572,8840716
74	18,25	550	0,365	42,80155642	58,42412451	0,311154429	419,7120623	572,906965
75	18,5	548	0,37	42,6459144	58,42490272	0,31481074	418,1858366	572,9145961
76	18,75	544	0,375	42,33463035	58,21011673	0,318453731	415,1333852	570,8084047
77	19	541	0,38	42,10116732	58,09961089	0,322083499	412,8440467	569,7247844
78	19,25	536	0,385	41,71206226	57,77120623	0,32570014	409,0284825	566,5044482
79	19,5	531	0,39	41,3229572	57,43891051	0,329303747	405,2129183	563,2459564

Engineering Stress vs Engineering Strain



BAJA Y

Arah Rol 0°

L = 50 mm

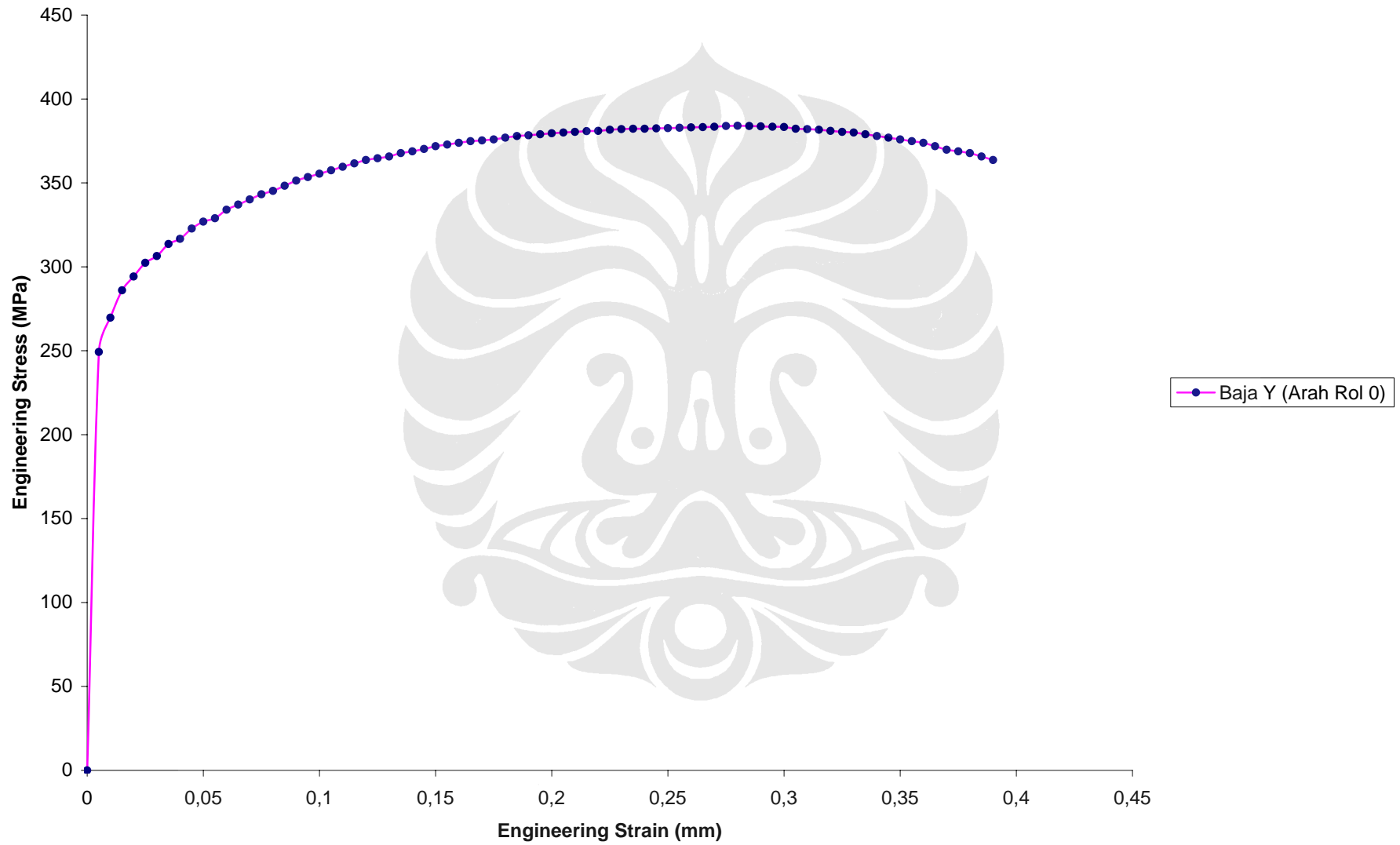
A0 = 9,60 mm²

No.	dl (mm)	P (Kg)	Strain	Stress	T. Stress	T. Strain	Stress (MPa)	T. Stress (MPa)
1	0	0	0	0	0	0	0	0
2	0,25	244	0,005	25,41666667	25,54375	0,004987542	249,2358333	250,4820125
3	0,5	264	0,01	27,5	27,775	0,009950331	269,665	272,36165
4	0,75	280	0,015	29,16666667	29,60416667	0,014888612	286,0083333	290,2984583
5	1	288	0,02	30	30,6	0,019802627	294,18	300,0636
6	1,25	296	0,025	30,83333333	31,60416667	0,024692613	302,3516667	309,9104583
7	1,5	300	0,03	31,25	32,1875	0,029558802	306,4375	315,630625
8	1,75	307	0,035	31,97916667	33,0984375	0,034401427	313,5877083	324,5632781
9	2	310	0,04	32,29166667	33,58333333	0,039220713	316,6520833	329,3181667
10	2,25	316	0,045	32,91666667	34,39791667	0,044016885	322,7808333	337,3059708
11	2,5	320	0,05	33,33333333	35	0,048790164	326,8666667	343,21
12	2,75	322	0,055	33,54166667	35,38645833	0,053540767	328,9095833	346,9996104
13	3	327	0,06	34,0625	36,10625	0,058268908	334,016875	354,0578875
14	3,25	330	0,065	34,375	36,609375	0,062974799	337,08125	358,9915313
15	3,5	333	0,07	34,6875	37,115625	0,067658648	340,145625	363,9558188
16	3,75	336	0,075	35	37,625	0,072320662	343,21	368,95075
17	4	338	0,08	35,20833333	38,025	0,076961041	345,2529167	372,87315
18	4,25	341	0,085	35,52083333	38,54010417	0,081579987	348,3172917	377,9242615
19	4,5	344	0,09	35,83333333	39,05833333	0,086177696	351,3816667	383,0060167
20	4,75	346	0,095	36,04166667	39,465625	0,090754363	353,4245833	386,9999188
21	5	348	0,1	36,25	39,875	0,09531018	355,4675	391,01425
22	5,25	350	0,105	36,45833333	40,28645833	0,099845335	357,5104167	395,0490104
23	5,5	352	0,11	36,66666667	40,7	0,104360015	359,5533333	399,1042
24	5,75	354	0,115	36,875	41,115625	0,108854405	361,59625	403,1798188

25	6	356	0,12	37,08333333	41,53333333	0,113328685	363,6391667	407,2758667
26	6,25	357	0,125	37,1875	41,8359375	0,117783036	364,660625	410,2432031
27	6,5	358	0,13	37,29166667	42,13958333	0,122217633	365,6820833	413,2207542
28	6,75	360	0,135	37,5	42,5625	0,126632651	367,725	417,367875
29	7	361	0,14	37,60416667	42,86875	0,131028262	368,7464583	420,3709625
30	7,25	362,4	0,145	37,75	43,22375	0,135404637	370,1765	423,8520925
31	7,5	364	0,15	37,91666667	43,60416667	0,139761942	371,8108333	427,5824583
32	7,75	365	0,155	38,02083333	43,9140625	0,144100344	372,8322917	430,6212969
33	8	366	0,16	38,125	44,225	0,148420005	373,85375	433,67035
34	8,25	367	0,165	38,22916667	44,53697917	0,152721087	374,8752083	436,7296177
35	8,5	367,4	0,17	38,27083333	44,776875	0,157003749	375,2837917	439,0820363
36	8,75	368	0,175	38,33333333	45,04166667	0,161268148	375,8966667	441,6785833
37	9	369	0,18	38,4375	45,35625	0,165514438	376,918125	444,7633875
38	9,25	370	0,185	38,54166667	45,671875	0,169742775	377,9395833	447,8584063
39	9,5	370	0,19	38,58333333	45,91416667	0,173953307	378,3481667	450,2343183
40	9,75	371	0,195	38,64583333	46,18177083	0,178146185	378,9610417	452,8584448
41	10	371,6	0,2	38,70833333	46,45	0,182321557	379,5739167	455,4887
42	10,25	372	0,205	38,75	46,69375	0,186479567	379,9825	457,8789125
43	10,5	372,4	0,21	38,79166667	46,93791667	0,19062036	380,3910833	460,2732108
44	10,75	372,8	0,215	38,83333333	47,1825	0,194744077	380,7996667	462,671595
45	11	373	0,22	38,85416667	47,40208333	0,198850859	381,0039583	464,8248292
46	11,25	373,6	0,225	38,91666667	47,67291667	0,202940844	381,6168333	467,4806208
47	11,5	374	0,23	38,95833333	47,91875	0,207014169	382,0254167	469,8912625
48	11,75	374,2	0,235	38,97916667	48,13927083	0,21107097	382,2297083	472,0536898
49	12	374,24	0,24	38,98333333	48,33933333	0,21511138	382,2705667	474,0155027
50	12,25	374,4	0,245	39	48,555	0,21913553	382,434	476,13033
51	12,5	374,6	0,25	39,02083333	48,77604167	0,223143551	382,6382917	478,2978646
52	12,75	374,8	0,255	39,04166667	48,99729167	0,227135573	382,8425833	480,4674421
53	13	375	0,26	39,0625	49,21875	0,231111721	383,046875	482,6390625
54	13,25	375,2	0,265	39,08333333	49,44041667	0,235072122	383,2511667	484,8127258
55	13,5	375,4	0,27	39,10416667	49,66229167	0,2390169	383,4554583	486,9884321

56	13,75	375,8	0,275	39,14583333	49,9109375	0,242946179	383,8640417	489,4266531
57	14	376	0,28	39,16666667	50,13333333	0,246860078	384,0683333	491,6074667
58	14,25	375,8	0,285	39,14583333	50,30239583	0,250758718	383,8640417	493,2652935
59	14,5	375,6	0,29	39,125	50,47125	0,254642218	383,65975	494,9210775
60	14,75	375,4	0,295	39,10416667	50,63989583	0,258510695	383,4554583	496,5748185
61	15	375,24	0,3	39,0875	50,81375	0,262364264	383,292025	498,2796325
62	15,25	374,2	0,305	38,97916667	50,8678125	0,266203041	382,2297083	498,8097694
63	15,5	374	0,31	38,95833333	51,03541667	0,270027137	382,0254167	500,4532958
64	15,75	373,6	0,315	38,91666667	51,17541667	0,273836666	381,6168333	501,8261358
65	16	373	0,32	38,85416667	51,2875	0,277631737	381,0039583	502,925225
66	16,25	372,4	0,325	38,79166667	51,39895833	0,281412459	380,3910833	504,0181854
67	16,5	372	0,33	38,75	51,5375	0,285178942	379,9825	505,376725
68	16,75	371	0,335	38,64583333	51,5921875	0,288931292	378,9610417	505,9129906
69	17	370	0,34	38,54166667	51,64583333	0,292669614	377,9395833	506,4390417
70	17,25	369	0,345	38,4375	51,6984375	0,296394013	376,918125	506,9548781
71	17,5	368	0,35	38,33333333	51,75	0,300104592	375,8966667	507,4605
72	17,75	367	0,355	38,22916667	51,80052083	0,303801454	374,8752083	507,9559073
73	18	366	0,36	38,125	51,85	0,3074847	373,85375	508,4411
74	18,25	364	0,365	37,91666667	51,75625	0,311154429	371,8108333	507,5217875
75	18,5	362	0,37	37,70833333	51,66041667	0,31481074	369,7679167	506,5820458
76	18,75	361	0,375	37,60416667	51,70572917	0,318453731	368,7464583	507,0263802
77	19	360	0,38	37,5	51,75	0,322083499	367,725	507,4605
78	19,25	358	0,385	37,29166667	51,64895833	0,32570014	365,6820833	506,4696854
79	19,5	356	0,39	37,08333333	51,54583333	0,329303747	363,6391667	505,4584417

Engineering Stress vs Engineering Strain



BAJA Y

Arah Rol 90°

L = 50 mm

A0 = 9,60 mm²

No.	dl (mm)	P (Kg)	Strain	Stress	T. Stress	T. Strain	Stress (MPa)	T. Stress (MPa)
1	0	0	0	0	0	0	0	0
2	0,25	256	0,005	26,66666667	26,8	0,004987542	261,4933333	262,8008
3	0,5	272	0,01	28,33333333	28,61666667	0,009950331	277,8366667	280,6150333
4	0,75	282	0,015	29,375	29,815625	0,014888612	288,05125	292,3720188
5	1	294	0,02	30,625	31,2375	0,019802627	300,30875	306,314925
6	1,25	300	0,025	31,25	32,03125	0,024692613	306,4375	314,0984375
7	1,5	306	0,03	31,875	32,83125	0,029558802	312,56625	321,9432375
8	1,75	310	0,035	32,29166667	33,421875	0,034401427	316,6520833	327,7349063
9	2	315	0,04	32,8125	34,125	0,039220713	321,759375	334,62975
10	2,25	318	0,045	33,125	34,615625	0,044016885	324,82375	339,4408188
11	2,5	322	0,05	33,54166667	35,21875	0,048790164	328,9095833	345,3550625
12	2,75	326	0,055	33,95833333	35,82604167	0,053540767	332,9954167	351,3101646
13	3	328	0,06	34,16666667	36,21666667	0,058268908	335,0383333	355,1406333
14	3,25	332	0,065	34,58333333	36,83125	0,062974799	339,1241667	361,1672375
15	3,5	334	0,07	34,79166667	37,22708333	0,067658648	341,1670833	365,0487792
16	3,75	337	0,075	35,10416667	37,73697917	0,072320662	344,2314583	370,0488177
17	4	339	0,08	35,3125	38,1375	0,076961041	346,274375	373,976325
18	4,25	342	0,085	35,625	38,653125	0,081579987	349,33875	379,0325438
19	4,5	344	0,09	35,83333333	39,05833333	0,086177696	351,3816667	383,0060167
20	4,75	346	0,095	36,04166667	39,465625	0,090754363	353,4245833	386,9999188
21	5	347	0,1	36,14583333	39,76041667	0,09531018	354,4460417	389,8906458
22	5,25	349	0,105	36,35416667	40,17135417	0,099845335	356,4889583	393,920299
23	5,5	350	0,11	36,45833333	40,46875	0,104360015	357,5104167	396,8365625
24	5,75	352	0,115	36,66666667	40,88333333	0,108854405	359,5533333	400,9019667

25	6	354	0,12	36,875	41,3	0,113328685	361,59625	404,9878
26	6,25	355	0,125	36,97916667	41,6015625	0,117783036	362,6177083	407,9449219
27	6,5	357	0,13	37,1875	42,021875	0,122217633	364,660625	412,0665063
28	6,75	358	0,135	37,29166667	42,32604167	0,126632651	365,6820833	415,0491646
29	7	359	0,14	37,39583333	42,63125	0,131028262	366,7035417	418,0420375
30	7,25	360	0,145	37,5	42,9375	0,135404637	367,725	421,045125
31	7,5	361	0,15	37,60416667	43,24479167	0,139761942	368,7464583	424,0584271
32	7,75	362	0,155	37,70833333	43,553125	0,144100344	369,7679167	427,0819438
33	8	363	0,16	37,8125	43,8625	0,148420005	370,789375	430,115675
34	8,25	364	0,165	37,91666667	44,17291667	0,152721087	371,8108333	433,1596208
35	8,5	364,5	0,17	37,96875	44,4234375	0,157003749	372,3215625	435,6162281
36	8,75	365	0,175	38,02083333	44,67447917	0,161268148	372,8322917	438,0779427
37	9	366	0,18	38,125	44,9875	0,165514438	373,85375	441,147425
38	9,25	367	0,185	38,22916667	45,3015625	0,169742775	374,8752083	444,2271219
39	9,5	367,25	0,19	38,25520833	45,52369792	0,173953307	375,1305729	446,4053818
40	9,75	367,5	0,195	38,28125	45,74609375	0,178146185	375,3859375	448,5861953
41	10	367,75	0,2	38,30729167	45,96875	0,182321557	375,6413021	450,7695625
42	10,25	368	0,205	38,33333333	46,19166667	0,186479567	375,8966667	452,9554833
43	10,5	368,25	0,21	38,359375	46,41484375	0,19062036	376,1520313	455,1439578
44	10,75	368,5	0,215	38,38541667	46,63828125	0,194744077	376,4073958	457,3349859
45	11	368,75	0,22	38,41145833	46,86197917	0,198850859	376,6627604	459,5285677
46	11,25	369	0,225	38,4375	47,0859375	0,202940844	376,918125	461,7247031
47	11,5	370	0,23	38,54166667	47,40625	0,207014169	377,9395833	464,8656875
48	11,75	370	0,235	38,54166667	47,59895833	0,21107097	377,9395833	466,7553854
49	12	370	0,24	38,54166667	47,79166667	0,21511138	377,9395833	468,6450833
50	12,25	370	0,245	38,54166667	47,984375	0,21913553	377,9395833	470,5347813
51	12,5	370	0,25	38,54166667	48,17708333	0,223143551	377,9395833	472,4244792
52	12,75	370	0,255	38,54166667	48,36979167	0,227135573	377,9395833	474,3141771
53	13	370	0,26	38,54166667	48,5625	0,231111721	377,9395833	476,203875
54	13,25	370	0,265	38,54166667	48,75520833	0,235072122	377,9395833	478,0935729
55	13,5	370	0,27	38,54166667	48,94791667	0,2390169	377,9395833	479,9832708

56	13,75	370	0,275	38,54166667	49,140625	0,242946179	377,9395833	481,8729688
57	14	369	0,28	38,4375	49,2	0,246860078	376,918125	482,4552
58	14,25	368,5	0,285	38,38541667	49,32526042	0,250758718	376,4073958	483,6835036
59	14,5	368	0,29	38,33333333	49,45	0,254642218	375,8966667	484,9067
60	14,75	367,5	0,295	38,28125	49,57421875	0,258510695	375,3859375	486,1247891
61	15	367	0,3	38,22916667	49,69791667	0,262364264	374,8752083	487,3377708
62	15,25	366,5	0,305	38,17708333	49,82109375	0,266203041	374,3644792	488,5456453
63	15,5	366	0,31	38,125	49,94375	0,270027137	373,85375	489,7484125
64	15,75	365	0,315	38,02083333	49,99739583	0,273836666	372,8322917	490,2744635
65	16	364,5	0,32	37,96875	50,11875	0,277631737	372,3215625	491,4644625
66	16,25	364	0,325	37,91666667	50,23958333	0,281412459	371,8108333	492,6493542
67	16,5	362	0,33	37,70833333	50,15208333	0,285178942	369,7679167	491,7913292
68	16,75	361	0,335	37,60416667	50,2015625	0,288931292	368,7464583	492,2765219
69	17	360	0,34	37,5	50,25	0,292669614	367,725	492,7515
70	17,25	359	0,345	37,39583333	50,29739583	0,296394013	366,7035417	493,2162635
71	17,5	358	0,35	37,29166667	50,34375	0,300104592	365,6820833	493,6708125
72	17,75	356	0,355	37,08333333	50,24791667	0,303801454	363,6391667	492,7310708
73	18	354	0,36	36,875	50,15	0,3074847	361,59625	491,7709
74	18,25	352	0,365	36,66666667	50,05	0,311154429	359,5533333	490,7903
75	18,5	350	0,37	36,45833333	49,94791667	0,31481074	357,5104167	489,7892708
76	18,75	346	0,375	36,04166667	49,55729167	0,318453731	353,4245833	485,9588021
77	19	340	0,38	35,41666667	48,875	0,322083499	347,2958333	479,26825

Engineering Stress vs Engineering Strain

