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Instruction on the use of tinius-olsen 0-120k machine for testing tension coupons, September, 1967

S. Desai

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May 2, 1969

MEMORANDUM

To: J. H. Daniels / A. Ostapenko
    G. C. Driscoll / R. G. Slutter
    J. W. Fisher / L. Tall
    L. W. Lu

From: L. S. Beedle

Subject: Tension Testing Procedure

The enclosed report No. 237.44 Draft proposes a standard procedure for obtaining a wide range of mechanical properties from a tension test. Please study the report carefully and give me your comments by May 29, 1969. A few questions we want to look at closely are:

1. Will machining modify specimen properties as a result of cold working?
2. Will it be more convenient to organize data-sheets into three parts:
   (a) Data recorded during the test
   (b) Computations
   (c) Summary of the mechanical properties

3. The times is being used only during the second run of the test. This means that the strain-rate corresponding to the recording of static and dynamic yield loads is not being observed. Is it necessary to have a new recorder sheet for every run so that the strain-rate is observed on every run.

Lynn S. Beedle

LSB:pa
TENSION TESTING PROCEDURE

by

Suresh Desai

February 1969

Fritz Engineering Laboratory
Department of Civil Engineering
Lehigh University
Bethlehem, Pennsylvania
This report contains a step-by-step procedure for testing tension specimens (8 in. gage) with a view to obtaining a wide range of mechanical properties. The procedure utilizes a Tinius-Olsen 120 kip screw-power type universal testing machine and two types of extensometers. One of these is a mechanical dial gage and the other is the autographic extensometer with a drum recorder made available as an accessory with the testing machine. Comments elucidating the procedure are added with a view to facilitating adoption to different needs or equipment. A detailed description of the machine and its accessories is available in a separate report.  

This report is an attempt to update the work done earlier by A. T. Gozum towards evolving a standard procedure for tension testing. The procedure described was evolved as a result of the experience gained on a series of tension tests in connection with Project 343 - "Plastic Design in A572 (Grade 65) Steel" at the Fritz Engineering Laboratory, Department of Civil Engineering, Lehigh University, Bethlehem, Pennsylvania. The project is sponsored by the American Institute of Steel Construction. Dr. L. S. Beedle is Director of the Laboratory and Dr. D. A. VanHorn is the Department Chairman.

Many from the Structural Metals Division of the Laboratory have contributed to this work. Drs. L. S. Beedle, G. C. Driscoll, J. W. Fisher, L. W. Lu, A. Ostapenko, R. G. Slutter, L. Tall, B. T. Yen and Messrs. S.N.S. Iyengar and L. C. Lim were particularly generous with their time. This help is gratefully acknowledged.
Miss Karen Philbin typed this report, Mr. J. Gera prepared the drawings and Mr. Richard Sopko photographed the pictures. To all of them sincere thanks are due.
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1. **EQUIPMENT REQUIRED**

1. 120 kip T.O. Machine with the following accessories:
   a. Flat wedge grips
   b. Grip lines
   c. Grip retainers with connecting bolts and grip spreaders with screws.
   d. Grip cranks
   e. 8" gage autographic extensometer complete with the recorder.

2. 8" Extensometer with a mechanical dial gage.

3. A pair of calipers

4. 0"-1" and 1"-2" micrometers

5. Four pieces of shock-cord, each about 15" long

6. Scribe and center punch

7. Autographic recorder sheets of appropriate load range.

8. Automatic timing device.

9. 12" scale with 100 divisions to an inch

10. Lead hammer

11. Light wooden or cardboard box

12. Rags for cleaning

13. Wax
2. PREPARING THE SPECIMEN

2.1 FABRICATION

1. Order the specimen to be cut to the shape shown in Fig. 11 and milled to a thickness of 1/4" or even less for high strength steels so that the 24 kip range can be used right up to the strain-hardening range of interest.

The recommended shape of the specimen conforms to the minimum standards set by ASTM A370. However, the length of the grip section is increased to 5" from the ASTM minimum of 3". This is done to provide adequate gripping even for the harder materials and to afford greater clearance for the instruments. The minimum fillet radius of 1 in. is increased to 2 in. to take advantage of the currently available equipment at Fritz Laboratory. Milling of the specimen is expected to provide a good surface for gripping and for the knife edge of the autographic extensometer while a thin specimen enable testing on a lower range to obtain greater accuracy.

2.2 PREPARING THE FACES

2. If the faces of the specimen are milled, wipe them clean with rags and proceed to the next step. If not, clean them thoroughly with light mineral oil and remove all loose mill scale. Remove all tight mill scale from the gripping ends by grinding. This mill scale which is usually very hard prevents the grips from biting deep into the parent metal and at higher loads, separates and acts like a lubricant causing the specimen to slip. Remove also any end burrs by
3. On the front face on which the mechanical dial gage will be mounted, mark the center of the gage length and the center line of the 1 1/2" width of the specimen by means of a scriber. Using this center line, mark scribe lines at every inch up to 4" on each side as shown in Fig. 2. Make sure that the end scribe lines fall within the straight reduced portion of the specimen.

4. Starting from the top end, mark eight punch marks using a center punch. Next, place the mechanical dial gage on the front face of the specimen with the fixed concial point of the dial gage engaging the top punch mark. Push the movable bar so as to obtain the minimum distance between the concial points and draw an arc on the specimen with the lower concial point. The ninth punch mark must lie beyond this arc. This precaution is to ensure free movement of the concial point and prevent any lost motion due to the gage length being smaller than the minimum distance between the concial points. Make the ninth punch mark and verify that the corresponding dial gage reading is greater than the minimum reading.
5. On the rear face of the specimen, make punch mark at the top to match the top punch mark on the front face. The conical point of the autographic extensometer will engage this punch mark.

2.4 MEASUREMENT OF CROSS SECTİONAL DIMENSIONS

6. Using micrometers, measure and record the width and thickness of the specimen at all the nine scribe marks. Also measure and record the gage length of the front face correct to 0.01 in.

2.5 INSPECTION FOR YIELD LINES

7. Inspect both faces of the specimen for yield lines due to straightening in the mill and record definitely the presence or absence of such yield lines. Record the pattern of yield lines on the data sheet making additional sketches if necessary to indicate the corresponding edges.
3. PREPARING THE MACHINE

3.1 CHECKING THE MACHINE

1. Switch on the machine with the main switch at the bottom of one side of the console. After a few minutes, the red light at the control lights up indicating that the machine is warmed up and ready for operation.

2. Set the speed selector to zero. Turn and set the control wheel firmly but not too tightly into the 'SLOW' position. Press the 'LOWER' knob and rotate the speed selector gradually to increase speed until the lower crosshead visibly moves. Lower the lower crosshead until there is a clear distance of at least 10" between the crossheads. Set the speed selector to zero.

   This step is to ensure that the machine is in proper working order and also to prevent jamming of the lower crosshead which sometimes occurs when it is suddenly moved at a high speed.

3. The loading speeds change with the aging of the electrical components and when a large number of tests are to be performed or where accurate speed is essential, it may be worthwhile checking the accuracy of the speed selector. To do this, run the machine at no load and measure the rate of separation of crossheads by a dial gage. The machine is built to maintain nearly the same crosshead speed under load.
3.2 ADJUSTMENT OF CROSSHEAD POSITIONS

4. Bring both the crossheads into a convenient working position. The position of the lower crosshead can be adjusted simply by manipulating the controls but the position of the upper crosshead must correspond to a set of pair of slots in the columns. To adjust the position of the upper crosshead, first turn and set the control wheel firmly but not too tightly into the 'FAST' position. Lift the steel collars and remove the split rings from all the four corners of the top of the upper crosshead. Insert the four lifting pins in the holes on the top of the lower crosshead. Push the 'STOP' and then the 'RAISE' button. It is a good practice to push the 'STOP' button before pushing the 'LOWER' or the 'RAISE' button. This will eliminate the possibility of sudden reversal and damage of the machine. When it is desired to move the lower crosshead in one direction only, use the speed selector for stopping, starting and running it.

Always set the control wheel firmly but not too tightly in the extreme positions of 'SLOW' and 'FAST'. Also, never raise the upper crosshead without removing the upper split rings.

5. Set the speed selector to 1 in. per min. and raise the lower crosshead until the lifting pins touch the upper crosshead and lift it by about an inch. Remove the split rings at the four corners of the bottom of the upper crosshead.

6. Next raise or lower the crossheads until the upper crosshead is about an inch above the slots in the columns corresponding to the desired position of the upper crosshead. Insert the split rings in these slots at the bottom corners of the upper crosshead and lower
the crossheads until the upper crosshead sits firmly on the split rings. Insert the split rings at the top four corners and cover them with the steel collars. Remove the lifting pins. Lower the lower crosshead until the clear distance between the crossheads is about eleven inches.

3.3 INSTALLING GRIPS AND RELATED ACCESSORIES

7. Examine the grips and note how far the gripping surface extends on the length of the grips. If the gripping surface does not extend fully, note the distance by which the surface is recessed from the edge. For best results, the entire length of the gripping surface should be utilized in gripping the specimen.

Using rags, clean thoroughly the flat wedge grips, the liners and the crosshead holes in which grips are housed. Wax the liners and wax the grips on their smooth sides. This will reduce the possibility of the specimen jamming between the grips. Usually, the specimen comes out loose with the shock of fracture but in the absence of fracture, waxed surfaces of the grips and liners are a great help in removing the specimen from the grips.

8. Mount a grip spreader with screws in each of the crosshead holes. The grip spreaders keep the grips apart and facilitate insertion of the specimen. See Fig. 3.

9. Mount a grip retainer under each crosshead using connection bolts. The lip of the grip retainer should be at the top touching the soffit of the crosshead so that the grips cannot slide below the soffit of the crosshead. This will prevent grips from slipping so far down as to get disengaged from the pinion. See Fig. 3.
10. Introduce the grips from the top of each crosshead and adjust them using the grip cranks until they move smoothly and in one level. Mount a grip retainer at the top of the upper crosshead as in Fig. 3. The lip should again be at the top to permit free vertical movement of the grips but prevent their popping out at fracture.

3.4 INSTALLING THE SPECIMEN

11. Introduce the specimen from the top of the upper crosshead after verifying the correct positions of the top and bottom ends as well as the front and rear faces. Lower the specimen until the lower end passes snugly between the grips in the lower crosshead. Introduce liners from the top of the upper crosshead. Provide the liners in pairs and in such numbers and thickness that the grips when locked recess at least 1/2 in. from the soffit of the upper crosshead. See Fig. 4. This minimum distance ensures that the grips and the crosshead do not get overstressed. If the grips are recessed more, the clearance for mounting the instruments or the grip length of the specimen will be reduced. Make sure that the arms of the liners sit firmly on the top of the upper crosshead.

12. Adjust the specimen vertically so that the level of the top of the specimen is flush with the level of the gripping surface. See Fig. 21.

13. Center the specimen visually with respect to the grips and lock the specimen at the top by lightly tapping the grip crank handle with the lead hammer. Always use the lead hammer for this to reduce shock on the pinion and the grip crank.
14. Stand at some distance from the machine and check the verticality of the specimen with distant vertical objects like columns. If the specimen requires a little adjustment, tap the bottom end lightly with the hammer while holding the top in a temporarily locked position.

15. Introduce from the top, into the lower crosshead, the same member and thickness of liners as used in the upper crosshead. The grips when locked must now recess about 1/2" below the top of the lower crosshead. Adjust the level of the lower crosshead so that the bottom end of the specimen is flush with the bottom edge of the gripping surface. See Fig. 4.

16. Check whether there is adequate clearance for mounting the autographic extensometer and the mechanical dial gage.

17. If the clearances are adequate, proceed to lock the specimen. If not, remove the liners from the top of the lower crosshead and introduce them from the bottom. Leave a gap of about 1/4" between the arms of the liners and the bottom of the lower crosshead. Although it is more favorable for gripping if the arms of the liners bear firmly on the bottom of the lower crosshead, it is advisable to leave this clearance to prevent jamming of the specimen at high loads. This constitutes a serious problem when the specimen does not fracture. It later on, the specimen slips excessively, provide wooden packing in the gap between the arms of the liners and the soffit of the bottom crosshead. The arms of the liners will thus seat more effectively on the crosshead and will be more effective in preventing slipping. In case of jamming, the wooden packing can be easily removed and the liners pushed down with the use of projecting arms to release the specimen.
18. If the clearances for the instruments are still inadequate reduce the gripping length by the same amount at the top and at the bottom. Obtain the maximum gripping length consistent with a proper mounting of the instruments. Figure 22 shows a specimen with both the instruments mounted.

Whenever the lower crosshead has to be moved for these adjustments, take care to release the lower end of the specimen. This will eliminate the danger of stressing the specimen as also the danger of damaging the machine when the lower crosshead is moved up.

19. Lock the specimen firmly by hitting the grip cranks a few times with the lead hammer. Lock the top first unless the liners in the bottom crosshead are introduced from the bottom, in which case, lock the bottom end of the specimen first. This is to prevent the liners of the bottom crosshead from falling down from the shock of hitting the upper grip crank.

3.5 CLEARING THE WEIGHING TABLE

20. Clear the weighing table completely and place the light wooden or cardboard box to receive the fractured specimen and protect the weighing table. Keep the weighing table clear at all times and do not place any accessories there because the load indicator will record this extra load.

3.6 ZEROING THE RANGES

21. Set the range selector knob to the desired load range and set the local pointer to zero. If you expect to use more than one range, zero the load pointer for all such ranges.
22. Turn and set the control wheel firmly but not too tightly to the 'SLOW' position. Set the speed selector to zero and push the 'STOP' and then the 'LOWER' knob.

3.7 GRIPPING THE SPECIMEN

23. Apply gripping pressure by pulling on the grip crank handles by hand and set the speed selector to 0.5 in. per min. When the load pointer begins to register load, keep loading to a value corresponding to about 5 ksi. Be careful not to overload the specimen. Unload, but leave a few pounds of load on. This will ensure that the specimen is still effectively gripped.

If the specimen slips, apply the gripping load at a much higher speed. Chances of overloading are now increased, so attempt this only after some experience on tension testing. However, gripping is more likely to be a problem with the harder and higher strength specimens where, if the specimens are thick enough, overloading will be less of a problem.
4. INSTRUMENTATION

4.1 THE DIAL GAGE (1/10,000 in.)

1. Adjust the dial gage so that when the main pointer is at zero, the pointer measuring hundreds is exactly at 0, 1, 2 --- etc. This is to avoid ambiguities in reading the dial in intermediate positions.

Adjust the position of the plunger of the gage by rotating the screw bearing on the plunger so that a very small reading is obtained on the dial. Lock the screw in this position. Make sure that there is no initial lost motion in the gage be pressing the plunger and observing the movement of the main pointer on the dial.

2. Attach the dial gage to the font face of the extensometer using two shock cords one at the top and one at the bottom. Tie the knots so that they are on the sides and not on the rear face of the specimen.

Adjust the cord tension so that it is even on both sides. Make sure that the conical points engage the punch marks effectively. Aline the plane of the dial gage parallel to the face of the specimen.

4.2 THE AUTOGRAPHIC EXTENSOMETER

3. Set the knife edge end to the long arm setting.

4. Plug in the autographic extensometer and switch on the standby switch to roll back the recorder drum to zero position.

5. Set the magnification knob to A, B and C in succession. If there is no significant change in the position of the drum in all these
three positions, it is an indication that the extensometer and the recorder are properly set. If not, a small adjustment in the position of the coil on the extensometer may be necessary. Always keep the pin on the drum clear of the stop pin using the recorder reset. This will ensure that there is no initial lost motion of the knife-edge of the extensometer. If it is found that the pin on the drum cannot be kept clear of the stop pin even with the recorder reset, adjust the position of the Atcotran differential transformer on the extensometer just enough to obtain a small clearance.

6. Shut off the standby switch under the recorder.

7. Attach the autographic extensometer to the rear face of the specimen by two shock cords, one at the top and one at the bottom. These shock cords should not pass over the mechanical dial gage, because this will make proper positioning of both instruments difficult.

Adjust the cord tension so that it is even on both sides. Make sure that the conical point engages the top punch mark firmly. Make sure that the knife edge of the extensometer bears fully on the specimen. This can be done by adjusting the cord tension on both sides of each cord.

8. Switch on the power and standby switches under the recorder.

9. Carefully, lift the knife edge off the specimen and place it back.

10. Rotate the load recording rod, disengage it from the gears behind the load dial, push it to the zero position and turn it to the desired range - half range or full range. Look behind the load dial and make sure that the rod engages the gears satisfactorily and is free to move.
11. Clean the pen, fill it with ink and check for proper flow. Mount the pen in the penholder but keep it clear of the drum. Set to magnification A. This gives a magnification factor of 400 so that with 8" gage, one division of 0.1 in. on the recorder sheet is equivalent to a strain of 0.00025 in./in.

12. Wrap a recorder shut of appropriate load range on the drum and fix it by slipping the metal paper clip over the edges of the drum. Set to zero using the resetting knob. Make sure that the pin on the drum is clear of the stop pin.

13. Mount the timing device and set it to five seconds but do not switch on the power. Check the pen of the timing device for proper flow.

14. Record the initial reading of the mechanical dial gage.
5. **RUNNING THE MACHINE AND RECORDING**

5.1 **CROSSHEAD SPEED**

1. Set the maximum pointer to touch the load pointer on the load dial.

2. Push the 'STOP' knob and then the 'LOWER' knob. Set the speed selector to 0.025 in./min. Use this crosshead speed until the specimen is strained well into strain-hardening.

In order to study the behavior of the material under static loads specimens should be tested at zero strain rate. This is not practical and the next best thing would be to test at a uniform low strain rate. Even this is not easy and most screw-power type machines including the 120 kip Tinius Olsen are built to maintain uniform crosshead speeds.

ASTM A370 specifies a maximum crosshead speed of 0.5 in. per min. for eight inch gage. However, to reduce the effect of strain rate on the behavior of the material, it is desirable to reduce the crosshead speed. The recommended speed of 0.025 in. per minute is the minimum indicated speed on the speed selector and is also the lowest speed at which the machine works smoothly at all loads.

5.2 **OBSERVATIONS**

3. Record the following:

   (a) Dial gage readings after a fixed interval of load. Choose the interval so that 15 to 25 intervals give the yield load. Always tap the dial gage gently a couple of times before taking a reading. This will reduce mechanical lags in the gage.
(b) All slips together with the corresponding loads as indicated by the maximum pointer. Set the maximum pointer back to touch the load pointer immediately after the load is recorded.

(c) Upper yield load, being the load indicated by the maximum pointer when yielding commences and the load drops.

(d) After the yield, record the load for every 0.005 in. of elongation.

(e) Set the maximum pointer back to touch the load pointer and just before the strain attains a value of 0.005 which corresponds to 2 in. on the strain axis of the recorder sheet, reduce the speed gradually until the machine stalls. Do not turn back the speed selector any more than is just necessary to stall the machine. Record the dynamic yield load as indicated by the maximum pointer.

This practice of stalling the motor is strongly recommended in preference to pushing the 'STOP' button or setting the speed selector to zero for two reasons: (i) It eliminates the 'backing up' of the motor and (ii) it averts the danger of pushing a wrong button.

Observe the load dial reading five minutes after stalling the machine. Record this as the static yield load. Also record the mechanical dial gage reading.

(f) Start the machine again setting the speed selector at 0.025 in./min. Read and record the dial gage and load everytime the dial gage pointer is at 0 or 50 on the dial. Stall the machine again at a strain of 0.0125 which corresponds to 5 in. on the strain axis of the recorder sheet. Record the maximum pointer load.

It is necessary to stop the first run in this way in order to obtain the important initial portion of the strain-hardening range of the curve in one run. If the first run is allowed to run for its full length and if the strain-hardening strain is large, the machine will have to be stopped soon after the onset of strain-hardening so that it will be impossible to get any reliable data in
in the strain-hardening range. However, if strain-hardening is found to commence at a strain of less than 0.0125, the run must be continued until the strain of 0.025 or 10" on the strain axis is reached.

(g) Lift the pen off the specimen and push the pen assembly out towards the end knob of the load recording rod. This will keep the trace of the second run distinct from the first. Lift the knife edge of the autographic extensometer off the specimen and allow the drum to rotate back. Set the pen back on paper and record the corresponding load from the load pointer and the dial gage reading.

   Everytime that the pen is required to be lifted up or set down, turn the end knob of the load recording rod in the direction of the selected range, so that the gear are firmly engaged before rotating the penholder clamp. This will guard against the gears disengaging while the penholder is being rotated.

(h) Set the speed selector at 0.025 ipm and switch on the power for the timing device.

(i) Continue to record the dial gage and load readings at every 0.005 in. of elongation for the full run of the drum.

4. As soon as the end of the recorder sheet is about to be reached, stall the machine, switch off the timing device. Remove the penholder from the clamp and the recorder sheet from the drum. Dismount the mechanical dial gage and the autographic extensometer.

5. Record the ultimate load as the maximum load indicated by the maximum pointer.

6. As the load drops, watch the load pointer carefully. Stay away from the specimen and warn passersby. Observe the load corresponding to the thud of fracture. Record this as the fracture load.
5.3 CHANGE OF RANGE

7. If at any stage of loading, you want to change the load range, simply turn the range selector knob to the desired range. Do not go beyond the capacity of any range. Preferably, change the range when the crosshead speed is zero and record the load in both the ranges. Do not change the range when the autographic recorder output is being obtained. Do not change to a lower range before making sure that the load falls within that range.

5.4 CHECKING THE INSTRUMENTS

8. If a general idea is available about the mechanical properties of the specimen under test, compute the elongation for the interval of load for which the dial gage is read in the elastic range. Also the load-strain curve in the elastic range can be computed. Check these values against the test values as the test proceeds. If no idea of the properties of the specimen is available, observe the functioning of the mechanical dial gage and the autographic extensometer and check that their readings are in broad agreement. One inch on the strain axis of the recorder is equal to an elongation of 0.02 in. on the mechanical dial gage. Correct any malfunctioning of the instruments in the elastic range only. Compare also, the strains computed from the mechanical dial gage with the strains recorded by the autographic recorder at least at two points (i) At static yield load and (ii) At the commencement of the second run on the recorder.

5.5 RELIABILITY OF LOAD DIAL READINGS

9. While taking load readings, always read the load dial. This will give more accurate values. Use the autographic curve only for a check.
5.6 SLIPPING OF THE SPECIMEN

10. If at any time during the elastic range, the specimen slips excessively, unload and dismount the autographic extensometer and the mechanical dial gage. Release the specimen and look for the causes of slip: Mill scale in grips or specimen, inadequate tightening, etc. and after setting right the deflects, start all over again.

5.7 WINDING UP THE TEST

11. Switch off the machine unless another test is immediately planned. Remove the grips, liners, grip spreaders and grip retainers and place them in the storage. Leave the working areas clean. Complete the log book.
6. MEASUREMENTS ON THE FRACTURED SPECIMEN

6.1 POSITION OF FRACTURE

1. Observe the position of the fracture with respect to the punch marks and record on the diagram on data sheet.

6.2 FINAL GAGE LENGTH

2. Place the fractured pieces with the matching surfaces of the fracture close together and the front face up. Measure, up to 0.01 in., using calipers the distance between the gage points and record it as the final gage length.

6.3 CROSS SECTIONAL DIMENSIONS OF THE FRACTURE

3. Measure the width at fracture on both pieces and the thickness at three locations on each piece as indicated in Fig. 6. Measure $w_1$, $t_1$, $t_2$, $t_3$ on the upper fractured surface and $w_2$, $t_4$, $t_5$ and $t_6$ on the lower fractured surface.

Record the width and thickness as the average of the corresponding measurements.

6.4 STORAGE OF THE FRACTURED SPECIMEN

4. Identify and retain the fractured pieces until the final submission of the summary report on the project. Classify as scrap later with the permission of the project director.
7. DATA SHEETS AND COMPUTATIONS

A set of data sheets and a set of typical test results are included at the end of this chapter.

A summary of the quantities to be recorded from the test are given below. The terms are defined in the chapter on 'Nomenclature'. A few of the terms are illustrated graphically in Fig. 6.

From the specimen:
1. Thickness and width at nine locations,
2. Original gage length \( g_o \)
3. Final gage length after fracture \( g_f \)
4. Width at two locations and thickness at six locations on the fractured areas.

From the load dial:
1. Upper yield load (maximum pointer)
2. Dynamic yield load (maximum pointer)
3. Static yield load
4. Load readings corresponding to an elongation of 0.005 in. on the mechanical dial gage up to the end of the second run.
5. Load reading at the commencement of the second run on the recorder
6. Ultimate load (maximum pointer)
7. Fracture load
From the mechanical dial gage

1. Readings corresponding to a fixed increment of load in the elastic range.

2. Reading corresponding to static yield load

3. Reading corresponding to the commencement of the second run on the recorder.

Compute the following:

From the specimen:

1. Average thickness and width. Take their product as the average original area \( A_0 \) of the cross section.

2. Elongation = \( g_f - g_o \)

3. Reduced area \( A_f = \) Average reduced thickness \( \times \) average reduced width. Reduction of area = \( A_0 - A_f \) and Percent Reduction of area = \( 100 \times \) Reduction of area/\( A_0 \)

From the Load Dial:

1. Upper yield stress \( \sigma_{uy} = \) Upper yield load/\( A_0 \)

2. Dynamic yield stress \( \sigma_{yd} = \) Dynamic yield load/\( A_0 \)

3. Static yield stress \( \sigma_{ys} = \) Static yield load/\( A_0 \)

4. Ultimate strength \( \sigma_u = \) Ultimate load/\( A_0 \)

5. Fracture stress \( \sigma_f = \) Fracture load/\( A_0 \)

From the load dial and the mechanical dial gage readings:

1. Construct a stress-strain curve in the strain-hardening range and using figure 7, compute strain-hardening strain \( \varepsilon_{st} \) and strain-hardening modulus \( E_{st} \) by two approaches: \( E_{st2} \) and \( E_{st3(b)} \).
2. Strain corresponding to static yield load and the commencement of the second run on the recorder

From the recorder sheet

1. Proportional limit \( \sigma_p \) = Load corresponding to \( \Delta \varepsilon = 0.0001/A_0 \).

See Fig. 8.

2. \( \varepsilon_{st1} \), \( E_{st1} \) (see Fig. 8), \( E_{st2} \), \( E_{st3(a)} \). For computing \( E_{st3(a)} \), modify \( \varepsilon_{st} \) to a value obtained by the intersection of the stress-strain curve of the yield stress level in the plateau and the tangent to the curve in the strain-hardening range. This tangent is drawn as the average value in an increment of 0.002 in./in. after the apparent onset of strain-hardening.
TENSION TEST

Date: __________________________
Temperature: ______________________
Tested by: _________________________
Machine used: ______________________
Gages used: ________________________
Scales: ____________________________
(Automatic Recorder)
Crosshead Speed: ________________

Measurments

<table>
<thead>
<tr>
<th>Thickness (in.)</th>
<th>Width (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>(average)</td>
<td>(average)</td>
</tr>
</tbody>
</table>

Any Yield Lines?

Gage Length: ________________ in.
Final Gage Length: ________________ in.
(Average Area): ________________ sq. in.

Indicate Fracture on Sketch.

Measurements on Fracture Surface

\[ w_1 = \quad w_2 = \]
\[ t_1 = \quad t_2 = \quad t_3 = \quad t_4 = \quad t_5 = \quad t_6 = \]

Reduced Area: ________________ in. x ________________ in. = ________________ sq. in.

Loads

<table>
<thead>
<tr>
<th>Upper Yield Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Yield Load</td>
</tr>
<tr>
<td>((\varepsilon = 0.005))</td>
</tr>
<tr>
<td>Static Yield Load</td>
</tr>
<tr>
<td>((\varepsilon = 0.005))</td>
</tr>
<tr>
<td>Ultimate Load</td>
</tr>
<tr>
<td>Fracture Load</td>
</tr>
</tbody>
</table>

RESULTS: (Attach load elongation curve and supporting calculations)

Proportional Limit
(\(\Delta\varepsilon = 0.0001\))
Upper Yield Stress
Dynamic Yield Stress
(\(\varepsilon = 0.005\))
Static Yield Stress
(\(\varepsilon = 0.005\))
Ultimate Stress
Fracture Stress
Strain at Strain Hardening: Auto: ________________ %
Dial: ________________ %
Percent Elongation ________________ %
Percent Reduction of Area ________________ %

Strain-Hardening Modulus:
Auto: \(E_{st1}\) ________________ ksi
\(E_{st2}\) ________________ ksi
\(E_{st3(a)}\) ________________ ksi
Dial: \(E_{st2}\) ________________ ksi
\(E_{st3(b)}\) ________________ ksi
**Supporting Calculations**

Original Area = _____ sq. in.

<table>
<thead>
<tr>
<th>LOAD (kips)</th>
<th>STRESS (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional Limit (Δε = 0.0001)</td>
<td></td>
</tr>
<tr>
<td>Upper Yield</td>
<td></td>
</tr>
<tr>
<td>Dynamic Yield</td>
<td></td>
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<tr>
<td>Static Yield</td>
<td></td>
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<tr>
<td>Ultimate</td>
<td></td>
</tr>
<tr>
<td>Fracture</td>
<td></td>
</tr>
</tbody>
</table>

Original Length (Gage Length) = _____ in.

<table>
<thead>
<tr>
<th>STRAINS</th>
<th>ELONGATION (in.)</th>
<th>STRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain at Strain Hardening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage Elongation</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>FINAL AREA (sq.in.)</th>
<th>ORIGINAL AREA (sq. in.)</th>
<th>REDUCTION BY PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage Reduction of Area</td>
<td></td>
<td>(100) = ___%</td>
</tr>
</tbody>
</table>

Specimen No. __________
<table>
<thead>
<tr>
<th>Load kips</th>
<th>Dial Reading</th>
<th>Extension $\times 10^4$</th>
<th>Strain $\times 10^5$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
TENSION TEST

Date: Sunday, Aug. 25, 1968
Temperature: Room
Tested by: S. Desai & S. Iyengar
Machine used: Tinius-Olsen 120 k
Gages used: Mounted Dial Gage, Autographic Recorder
Scales: 1 Small Div.= 500 lbs. (Load Axis)
(Automatic Recorder) 1 Small Div.= 0.00025 in./in. (strain axis)
Crosshead Speed: 0.025 ipm (and see notes)

Location of Specimen in cross section

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Loads (Kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>Width</td>
</tr>
<tr>
<td>(in.)</td>
<td>(in.)</td>
</tr>
<tr>
<td>0.380</td>
<td>1.499</td>
</tr>
<tr>
<td>0.380</td>
<td>1.499</td>
</tr>
<tr>
<td>0.381</td>
<td>1.501</td>
</tr>
<tr>
<td>0.380</td>
<td>1.500</td>
</tr>
<tr>
<td>0.380</td>
<td>1.503</td>
</tr>
<tr>
<td>0.380</td>
<td>1.503</td>
</tr>
<tr>
<td>0.381</td>
<td>1.501</td>
</tr>
<tr>
<td>0.382</td>
<td>1.500</td>
</tr>
<tr>
<td>3.424</td>
<td>13.510</td>
</tr>
<tr>
<td>0.380</td>
<td>1.501</td>
</tr>
</tbody>
</table>

Any Yield Lines? No
Gage Length: 8.01 in.
Final Gage Length: 9.78 in.
(Average Area): 0.570 sq. in.

Indicate Fracture on Sketch.

Measurements on Fracture Surface

\[ w_1 = 1.144 \quad w_2 = 1.140 \]
\[ t_1 = 0.282 \quad t_2 = 0.253 \quad t_3 = 0.292 \]
\[ t_4 = 0.288 \quad t_5 = 0.262 \quad t_6 = 0.300 \]
Reduced Area: 1.142in. x 0.279 in. = 0.319 sq.in.

Strain-Hardening Modulus:

Auto: \[ E_{st1} = 4,210 \text{ ksi} \]
\[ E_{st2} = 601 \text{ ksi} \]
\[ E_{st3(a)} = 950 \text{ ksi} \]
Dial: \[ E_{st2} = 589 \text{ ksi} \]
\[ E_{st3(b)} = 1,122 \text{ ksi} \]
**Supporting Calculations**

Original Area = 0.57 sq. in.

<table>
<thead>
<tr>
<th>LOAD (kips)</th>
<th>STRESS (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional Limit ($\Delta e = 0.0001$)</td>
<td>30.5</td>
</tr>
<tr>
<td>Upper Yield</td>
<td>--</td>
</tr>
<tr>
<td>Dynamic Yield</td>
<td>33.55</td>
</tr>
<tr>
<td>Static Yield</td>
<td>32.50</td>
</tr>
<tr>
<td>Ultimate</td>
<td>45.90</td>
</tr>
<tr>
<td>Fracture</td>
<td>35.80</td>
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</table>

Original Length (Gage Length) = 8.01 in.

<table>
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<th>STRAINS</th>
<th>ELONGATION (in.)</th>
<th>STRAIN</th>
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</thead>
<tbody>
<tr>
<td>Strain at Strain Hardening</td>
<td>53.8 divs.</td>
<td>0.01345</td>
</tr>
<tr>
<td>Percentage Elongation</td>
<td>9.78-8.01</td>
<td>22.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FINAL AREA (sq.in.)</th>
<th>ORIGINAL AREA (sq. in.)</th>
<th>Reduction by Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.312</td>
<td>0.570</td>
<td>0.258(100) = 45.2%</td>
</tr>
<tr>
<td></td>
<td>0.570</td>
<td></td>
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<td>Load kips</td>
<td>Dial Reading</td>
<td>Extension $\times 10^4$</td>
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<tr>
<td>-----------</td>
<td>--------------</td>
<td>-------------------------</td>
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<td>Load kips</td>
<td>Dial Reading</td>
<td>Extension $\times 10^4$</td>
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<tr>
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<td>------------------------</td>
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<td>33.55</td>
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<td>33.55</td>
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<td>742</td>
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<tr>
<td>33.55</td>
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<td>2300</td>
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<td>34.2</td>
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<td>34.45</td>
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<tr>
<td>34.75</td>
<td>2500</td>
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<tr>
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<td>Load kips</td>
<td>Dial Reading</td>
<td>Extension $\times 10^4$</td>
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<tr>
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<tr>
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<td>37.5</td>
<td>3150</td>
<td>1942</td>
</tr>
<tr>
<td>37.65</td>
<td>3200</td>
<td></td>
</tr>
<tr>
<td>42.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.90</td>
<td></td>
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</tr>
</tbody>
</table>
TEST NO. 4.14.5W
STRAIN (1 DIV. = 0.00025 IN./IN.)
ε_st:  Dial:  0.01365  
      Auto:  53.8 divns = 0.01345

Auto:  \[ E_{st1} = \frac{27}{45} \times 0.00025 \times \frac{1}{0.57} = 4210 \text{ ksi} \]

Load at \( \varepsilon_{st} + 0.003 = 34,900 \text{ lbs.} \)
Load at \( \varepsilon_{st} + 0.010 = 37,300 \text{ lbs.} \)

\[ E_{st2} = \frac{2400}{0.57} \times \frac{1}{0.007} \text{ psi} = \frac{2400}{7(0.57)} \text{ ksi} = 601 \text{ ksi} \]

\[ E_{st3(1)} = \frac{5.0}{37} \times (0.00025) \times \frac{1}{0.57} = 950 \text{ ksi} \]

Dial:  \[ E_{st2} = \frac{2.35}{0.07} \times 57 = 589 \text{ ksi} \]

Load at \( \varepsilon_{st} + 0.005 = 35.70 \)

\[ E_{st3(2)} = \frac{35.70 - 32.50}{0.57 \times 0.005} = \frac{0.64(1000)}{0.57} = 1122 \text{ ksi} \]

NOTES:  The specimen did not exhibit upper yield point.  A small slip occurred at a load of 42.90 k (after the second run on paper).  At the end of the second run on paper, speed was increased to 0.050 ipm.  After the ultimate load, (when load began to drop), at a load of 45.3 k, speed was further increased to 0.100 ipm.
8. CONDENSED SEQUENCE

A brief summary of the various steps involved is now given.

Since the tension test is best conducted by a group of two workers, the recommended subdivision of the work between the two, designated A and B is also indicated

\[ A \quad B \]

8.1 EQUIPMENT REQUIRED

1. Collect the required equipment and the accessories

8.2 PREPARING THE SPECIMEN

2. Clean and grind the specimen. See Fig. 2

3. Make scribe lines and punch marks. See Fig. 2

4. Measure thickness, width and \( g_0 \)  
   Record the measurements taken by A.

5. Look for yield lines and record.

8.3 PREPARING THE MACHINE

6. Clean the crosshead holes, grips and gripliners. Wax the gripliners and the grips. Install the grip spreaders and the grip retainers. See Fig. 3  
   Check the working of the machine. Bring the crossheads into a convenient working position. Install the grips.

7. Install the specimen and the gripliners. Adjust the total thickness of gripliners, position of specimen and lower crosshead to obtain conditions shown in Fig. 4. Aline the specimen.  
   Manipulate the grip crank to hold and release the specimen while A adjusts to the position shown in Fig. 21. Check the position and alinement of the specimen. Check the position of grips. Check the clearance for the instruments.
8. Clear the weighing table.
Place the light box on it

9. Keep pulling

8.4 MOUNTING THE MECHANICAL DIAL GAGE

10. Tie the shock cords.
   Equalize the cord
tension and aline the
gage parallel to the
specimen

11. Hold the mechanical
dial gage in position
on the front face of
the specimen.

12. Check that the conical
points engage the punch
marks satisfactorily.
Check the alinement of
the gage.

8.5 MOUNTING THE AUTOGRAPHIC EXTENSOMETER

12. Check that the knife edge
has long arm setting.
Plug in the extensometer.

13. Tie the shock cords. Ad-
just cord tension to secure
full bearing of the knife
dege on the specimen.

14. Switch on the power
and standby switches.
Check the zero error
and the working of the
recorder reset. Switch
off the standby switch.

15. Lift the knife edge off
the specimen and place
it back.

15. Zero the load recording
rod and set to the desired
range. Set the magnification
knob to A.
<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.</td>
<td>Mount the timing device. Check the pen for proper flow.</td>
<td>Fix and zero the recorder sheet.</td>
</tr>
<tr>
<td>17.</td>
<td></td>
<td>Mount the pen assembly and check the pen for proper flow.</td>
</tr>
<tr>
<td>18.</td>
<td>Check the position of the load recording rod behind the load dial.</td>
<td></td>
</tr>
</tbody>
</table>

8.6 RUNNING THE MACHINE AND RECORDING

19. Read and record the initial reading of the dial gage.

20. Run the machine at a crosshead speed of 0.025 ipm.

21. List the values of loads at which readings are to be taken in the elastic range.

22. Read and record the dial gage reading against the corresponding load when B calls 'Read'.

23. Read every slip and the minimum reading after every slip. Record loads read by B.

24. Check approximately the agreement between the mechanical dial gage and the autographic extensometer.

25. Record the upper yield load

26. Read the upper yield load from the maximum pointer. Set back the maximum pointer to touch the load pointer.

27. Just before the strain is about to reach 2 in. on the strain axis of the graph, stall the machine.
27. Record the dynamic yield load and the static yield load. Read and record the dial gage reading corresponding to the static yield load. Check that the elongation on the dial gage is about 0.04 in.

28. Read the dynamic yield load from the maximum pointer. Wait for five minutes after stalling the machine and read the static yield load.

29. Call 'Read' everytime the dial gage reaches a value listed in step 28.

30. Read the dial gage at each slip and read the minimum value after each slip.

31. List values differing by 50 divisions on the dial gage.

32. Lift the knife edge off the specimen for a few seconds to allow the drum to roll back completely.

33. Stall the machine at about 5 in. on the strain axis. From the maximum pointer, read and record the corresponding load. Lift the pen off the recorder sheet.

34. Call 'Read' everytime the dial gage reaches a value listed in step 28.
35. Near the end of the second run, take off the dial gage.

36. Take off the autographic extensometer.

37. Read and record the ultimate load.

38. Read and record the fracture load.

8.7 MEASUREMENTS ON THE FRACTURED SPECIMEN

39. Observe and sketch the position of the fracture on the data sheet.

40. Match the fractured surfaces closely and measure $\gamma_f$.

41. Measure $w_1, w_2, t_1, t_2, t_3, t_4, t_5$ and $t_6$. See Fig. 23.

42. Compute average thickness, average width and $A_o$.

43. Compute $\sigma_{uy}$, $\sigma_{yd}$, $\sigma_{ys}$, $\sigma_u$ and $\sigma_f$.

44. From mechanical dial gage readings, compute $\varepsilon_{st}$, $E_{st2}$ and $E_{st3(b)}$.

45. From autographic extensometer, compute $\sigma_p$, $\varepsilon_{st}$, $E_{st1}$, $E_{st2}$ and $E_{st3(a)}$.

46. Compute $A_f$ and Percent Reduction of Area.

47. Compute Percent Elongation.
9. NOMENCLATURE

Symbols

\( A_0 \) = Original area of the cross section of the specimen

\( A_f \) = Reduced area at fracture of the specimen

\( E \) = Young's modulus, ksi, taken as 29,600 ksi

\( E_{st} \) = Strain-hardening modulus, ksi

\( E_{st1} \) = Value of \( E_{st} \) in ksi obtained from the maximum initial slope of the autographic recorder curve at the apparent onset of strain hardening, judged by eye.

\( E_{st1(a)} \) = Value of \( E_{st} \) in ksi determined by curve fitting and used in Ramberg-Osgood stress-strain equation with three parameters.

\( E_{st1(b)} \) = Value of \( E_{st} \) in ksi determined using static stress levels at \( \varepsilon_{st} \) and \( \varepsilon_{st} + 0.002 \)

\( E_{st2} \) = Value of \( E_{st} \) in ksi obtained as the chord slope of the autographic recorder curve between strain increments 0.003 and 0.010 after the apparent onset of strain-hardening.

\( E_{st3(a)} \) = Value of \( E_{st} \) in ksi obtained by the method of least squares from the autographic recorder curve by selecting two strain intervals of 0.065 each after the onset of strain-hardening.

\( E_{st3(b)} \) = Value of \( E_{st} \) in ksi determined in the same way as \( E_{st3(a)} \) from readings taken from the dial gage and the corresponding readings of the load indicator.

\( g_0 \) = Original gage length

\( g_f \) = Final gage length after fracture

\( R_m \) = Maximum rotation capacity

\( r_y \) = Weak-axis radius of gyration

\( t \) = Thickness of the specimen; with subscripts as in Fig. 6

\( w \) = Width of the specimen; with subscripts as in Fig. 6
\begin{align*}
\varepsilon & = \text{Strain} \\
\dot{\varepsilon} & = \text{Strain rate, micro in./in./sec.} \\
\varepsilon_y & = \text{Strain at first yield, evaluated as } \varepsilon_{ys}/E \\
\varepsilon_{st} & = \text{Strain at onset of strain-hardening} \\
\sigma_p & = \text{Limit of proportionality in ksi as determined by an offset of 0.0001 in./in.} \\
\sigma & = \text{Stress, ksi} \\
\sigma_y & = \text{Yield stress, ksi stress} \\
\sigma_{uy} & = \text{Upper yield point, ksi} \\
\sigma_{ly} & = \text{Lower yield point, ksi} \\
\sigma_{yd} & = \text{Dynamic yield stress level, ksi} \\
\sigma_{ys} & = \text{Static yield stress level, ksi} \\
\sigma_{ym} & = \text{Yield stress level in a mill test, ksi} \\
\sigma_u & = \text{Tensile strength (ultimate strength), ksi} \\
\sigma_f & = \text{Fracture stress, ksi} \\
\end{align*}

\textbf{ABBREVIATIONS}

\begin{align*}
\text{AISC} & = \text{American Institute of Steel Construction} \\
\text{ASTM} & = \text{American Society for Testing and Materials} \\
\text{CRC} & = \text{Column Research Council} \\
\text{ipm} & = \text{inches per minute} \\
\text{ksi} & = \text{kips per square inch}
\end{align*}
Glossary

General Terms

Mechanical Properties - Those properties of a material that are associated with elastic and inelastic reaction when force is applied or that involve the relationship between stress and strain.

Strain - The unit change, due to force, in the size or shape of a body referred to its original size or shape. Strain is a non-dimensional quantity but it is frequently expressed in inches per inch.

Stress - The intensity at a point in a body of the internal forces or components of force that act on a given plane through the point. In this report, stress is always expressed in kips per square inch of original area.

Terms relating to Tension Testing

Ductility - The ability of a material to deform plastically before fracturing. Usually evaluated by elongation or reduction of area. Sometimes evaluated by uniform strain. Also related to $\varepsilon_{\text{st}}$.

Extensometer - A device for measuring linear strain.

Elongation - The increase in gage length after fracture of a tension test specimen usually expressed as a percentage of original gage length. In reporting values of elongation, the gage length shall be stated.

Fracture Stress - Stress, computed as the quotient of the force at the instant of fracture and the original area.
**Gage Length** - The original length of that portion of the specimen over which strain is determined.

**Necking** - The localized reduction of the cross-sectional area of a specimen which may occur during stretching.

**Proportional Limit** - The greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain. In this report, measured with an offset of 0.001 in./in. on the stress-strain curve.

**Reduction of Area** - The difference between the original cross-sectional area of a tension test specimen and the area of its smallest cross-section after fracture. The reduction of area is usually expressed as a percentage of the original cross-sectional area of the specimen.

**Relaxation** - Decrease in stress at a constant total elongation.

**Strain-hardening** - Increase in resistance to deformation after the material has undergone finite strain at a practically constant stress subsequent to yielding.

**Strain-hardening Modulus** - Ratio of increase in stress to increase in strain, usually measured over a finite strain in the strain-hardening range of the stress-strain curve.

**Tensile Strength or Ultimate Strength** - The maximum tensile stress which a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross-sectional area of the specimen.

**Uniform Strain** - Strain at maximum load in a tension test.
Yield Point - The first stress in the material less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress. When such increase in strain is accompanied by a decrease in stress, the specimen is said to have recorded an 'upper yield point'. 'Lower yield point' is the lowest stress immediately after the upper yield point is recorded and before the yield stress level stabilizes.

Yield Stress Level - The average stress during actual yielding in the plastic range. For structural steel, the stress remains fairly constant from the yield point up to the level of strain hardening provided the strain rate is held constant. Dynamic yield stress level corresponds to a crosshead speed of 0.025 ipm and the 'static yield stress level' is the yield stress level for zero strain rate. In this report both were measured at a strain of 0.005 in./in. as required by ASTM A370.

Young's Modulus - Ratio of tensile or compressive stress to corresponding strain below the proportional limit.

STATISTICAL TERMS

Average - Sum of n numbers divided by n.

Median - The middlemost value

Standard Deviation - The square root of the average of the squares of the deviation of the numbers from their average. Theoretical estimated percentage of total observations lying within the range of Average $\pm 1.0 \times$ Standard Deviation is 68.3.

Coefficient of Variation - Ratio of 'Standard Deviation' to 'Average' expressed as a percentage.
10. **FIGURES**

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FIG. 1 SHAPE OF THE SPECIMEN
By Light Grinding (Not Necessary If Faces Are Milled)

Remove Tight Mill Scale By Light Grinding To Provide Clean Surface For Seating Knife Edge

Check With The Gage Of The Mech. Dial Gage Before Making This Punch Mark

Remove Tight Mill Scale By Light Grinding To Provide Clean Surface For Seating Knife Edge

Scribe Lines

Punch Marks

Front Face (For the Mechanical Dial Gage)

Rear Face (For the Autographic Extensometer)

FIG. 2 SCRIBE AND PUNCH MARKS ON THE FACES OF THE SPECIMEN
FIG. 3 FRONT VIEW OF SECTION THRU CROSSHEADS SHOWING THE ARRANGEMENT OF GRIP SPREADERS AND GRIP RETAINERS
Grip Liners

~

Gripping

Adjust Ends of Specimen to Make the Full Length of Gripping Surface Effective

Upper Crosshead

\[ \frac{1}{2}'' \]

Specimen

Gripping Surface

Lower Crosshead

\[ \frac{1}{2}'' \]

Grip Liners

Grips

FIG. 4 SIDE VIEW OF SECTION THRU CROSSHEADS SHOWING THE CORRECT POSITION OF THE SPECIMEN AND THE GRIPS
FIG. 5 A SPECIMEN WITH BOTH EXTENSOMETERS MOUNTED
$t_1, t_2, \text{ and } t_3$ are measured on the upper fractured surface.

$t_4, t_5, t_6$ are measured on the lower fractured surface.

**FIG. 6 MEASUREMENTS ON THE FRACTURED SPECIMEN**
FIG. 7 SKETCH DEFINING $E_{st1}$, $E_{st2}$ and $E_{st3}$
FIG. 8  SKETCH DEFINING $\sigma_p$, $\sigma_{uy}$, $\sigma_{ly}$, $\sigma_{yd}$ and $\sigma_{ys}$
11. REFERENCES

1. Desai, S.
   THE 120 KIP TINIUS-OLSEN MACHINE, Fritz Engineering Laboratory Report (In preparation)

2. Gozum, A. T.

3. Desai, S.

4. ASTM


6. Johnston, B. G., Editor

7. McClintock, F. A. and Argon, A. S., Editors