Instron
AVE
Advanced Video Extensometer

Reference Manual - Application Notes

M26-14059-EN Revision A

www.instron.com

Electromagnetic Compatibility

Where applicable, this equipment is designed to comply with International Electromagnetic Compatibility (EMC) standards.

To ensure reproduction of this EMC performance, connect this equipment to a low impedance ground connection. Typical suitable connections are a ground spike or the steel frame of a building.

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Chapter 1
Introduction

Outline

This section describes what is in this manual.

About this Manual

This manual is applicable to the Instron Advanced Video Extensometer (AVE).

The application notes contained in this manual are intended to help you get the best out of using your AVE with your test system in order to produce accurate and repeatable results.

Note: *Ensure that you have read and understood the AVE operating instructions supplied with your system.*

You are recommended to read through the whole of a chapter, so as not to miss any of the points discussed.

About Application Specific Techniques

All of the techniques described in this manual have been validated by Instron using the AVE unless otherwise stated.

Due to the extensive number of video extensometry applications, it has not been possible to verify them all with the AVE, so these unverified techniques are given as suggestions. However, as the features of the AVE negate many previous problems, e.g. reflection, Instron consider that if one of the validated techniques does not meet your testing requirements, then one of the suggested methods described will be a valid starting point to define a method specific to your application.

Please contact Instron if you experience any difficulties using the AVE.

Chapter 2
Marking Your Specimen

Outline

This section describes the recommended ways of marking your specimen when using your AVE.

Note: *There are some applications that need special marks, e.g. wire, these are discussed in "Application Specific Information" on page 3-1.*

Important Marking of specimens is the single most critical area regarding the use of video extensometry. The correct marking of your specimen will give you accurate and repeatable test results.

About Marking

Marking your specimen consists of:

- Selecting the material of mark to suit the specimen material.
- Selecting a colour for the marks that will contrast with the specimen colour **as seen by the camera**.
- Selecting the shape and size of the mark to suit the specimen profile
- Applying the marks to the specimen to give the best result.

If you are testing to a national or international standard, the gaugelength is often pre-defined. In these cases, you must apply the marks as specified. The marking instructions given in this manual must not be used to over-rule the requirements of recognised standards.

About Mark Materials

The marking materials supplied by Instron with your AVE are for generic testing and may not be suitable for your specimen material.

Be aware that ink and tape adhesive both contain solvents and that these solvents may affect the strength of your specimen.

You are advised to test your specimen as soon after applying the marks as possible to prevent possible degradation of your specimen. For high extension materials, the mark must still be in a pliable state when testing

If your specimen breaks where the mark is applied, you should consider an alternative marking material.

Selecting the Mark Material

There are two basic materials for marking specimens:

- Ink - Instron supply pens that, when used as specified in this chapter, will generate consistent marks which the camera will easily identify.
- Tape - Normally only used for dots. Applying tape lines is not discussed in this manual. Instron supply tape and dot applicators.

Other marking materials are discussed in the sections of this manual devoted to special applications.

See Also

"Instron Specimen Marking Items" on page 2-8

Selecting the Colour of the Mark

As discussed in the Operating Instructions supplied with your AVE, the camera is a monochromatic greyscale unit, the lighting is monochromatic red, the lighting array and the camera have polarising filters set at 90° to each other. Because of this, the camera sees many colours as dark grey or black. It also sees reflective surfaces as black. As a consequence, the best test results are commonly achieved with a white mark.

Some specimens change colour during tension testing, e.g. some plastics go “white”. As a first step, ensure that the mark colour contrasts with your specimen colour at all stages of the test.

Some specimens that appear white to the human eye do not appear as such to the camera and therefore also benefit from a white mark.

Recommendations

- Use white marks wherever possible.
- If the AVE cannot locate the white marks and you have ensured that they are of the correct shape, density and size change the marks to black.
- Do not use silver marks, as these appear black to the camera.

Suggestions

Note: *Suggestions have not been validated using the AVE.*

- For specimens that change colour, coat the specimen so that it resembles the finished colour and then choose a contrasting mark colour. Coatings must not affect the strength of your specimen and must remain pliable throughout the test.

Selecting the Type of Mark

Mark Shape

There are two types of mark shape:

- Dots - Solid circular shaped marks. The best results are achieved when the mark is as round as possible. Dots are required for transverse, or for axial with transverse strain measurement.
- Lines - Straight solid marks over the whole width of the specimen. Lines can only be used for axial strain measurement.

Mark Size

Table 2-1. Specimen Mark Dimension Guidelines

FOV mm	**60**	**200**	**500**
Minimum Dot Mark Diameter mm (in)	0.5 (0.02)	2 (0.08)	2 (0.08)
Recommended Dot Mark Diameter mm (in)	2 [a] (0.04)	4 (0.15)	4 (0.15)
Minimum Line Mark Thickness mm (in)	0.25 (0.01)	1 (0.04)	2.5 (0.1)
Recommended Line Mark Thickness mm (in)	1 (0.04)	2 (0.04)	5 (0.2)
Maximum Line Mark Thickness mm (in)	2.5 (0.1)	4 (0.15)	10 (0.39)

a. Use 1mm diameter marks when measuring axial and transverse together.

Real Time Errors

The larger the mark, the more real time is used in processing the data. If measuring axial and transverse strain simultaneously, you may generate an error if either set of marks are greater than the recommended diameter.

Mark Density

Marks must be of even density to prevent false edges being detected.

Marks need to be as dense as possible, especially on elastomeric specimens because the marks fade when stretched.

Instron Specimen Marking Items

Table 2-2. Specimen Marking Items

Part Number	Item	Comment
2663-841	Marker Pen White (box of 10)	10 pens supplied with AVE
2663-842	Marker Pen Black (box of 10)	2 pens supplied with AVE
T1697-5080	Dot Marking Fixture - Universal	Supplied with AVE
2663-601	Target Applicator - Metric	Optional Extra
2663-602	Target Applicator - US Customary	Optional Extra
41-4-55	Vinyl Tape White (25m roll)	1 roll of each supplied with target applicator
41-4-54	Vinyl Tape Black (25m roll)	

Applying Ink Dots

In general terms, the marks must be on the centre line of the specimen, equidistant about the centre point. Consult the specification of any standard you are using for the spacing of the dots, i.e. the specified gauge length.

A universal marking jig (Item T1697-5080) is provided with your AVE. See Figure 2-1. The jig has two hole sizes, to suit 2 mm and 4 mm marks set out so as to meet the common axial and transverse gauge lengths.

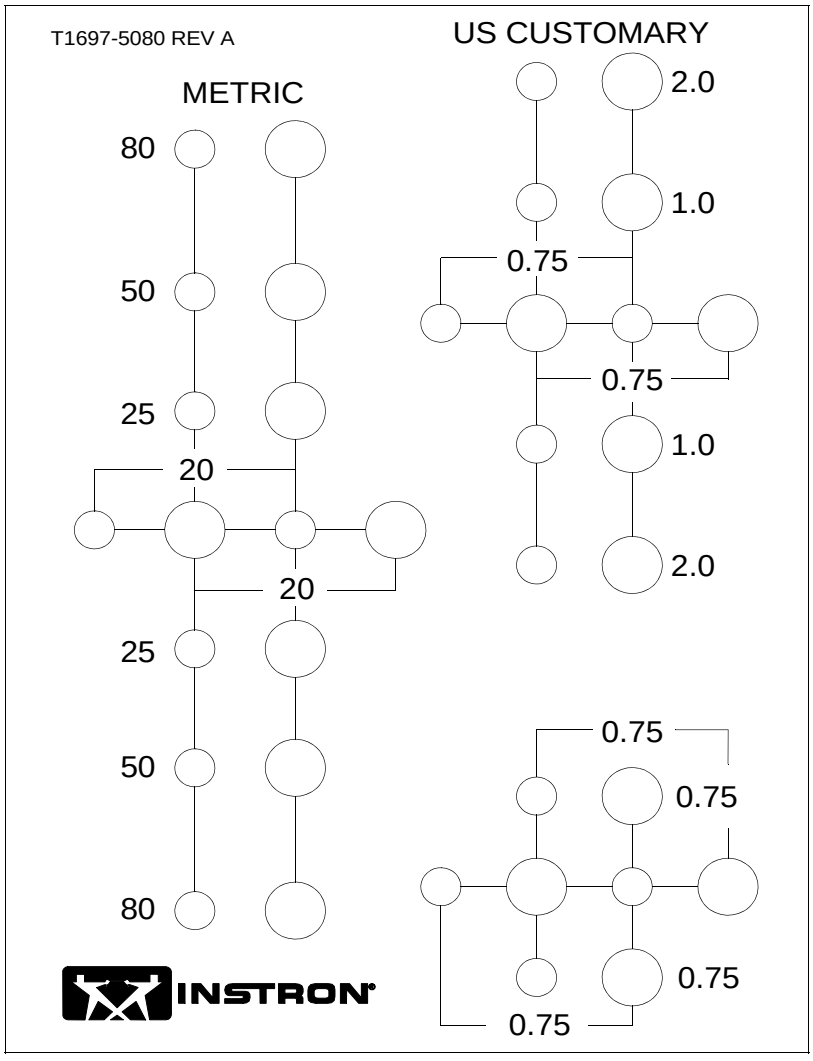

Figure 2-1. Universal Marking Jig

Using the Marking Jig

Notes: *The universal marking jig is designed to be used with the marker pens supplied with your AVE. The use of other pens may cause you to create marks that are not of a correct size.*

The marker pens supplied have spring loaded tips, which helps prevent excessive pressure being applied and thus reduce damage to the tip. Because the pen tips are fibre, prolonged use or rough specimen surfaces will cause the tip to wear and eventually produce marks that are oversize. Monitor the size of your marks produced by the marker pens and discard the pen if the marks are oversize.

1. Decide on the gauge length you need for the test you are to undertake.
2. Decide on the size of mark you need. See "Mark Size" on page 2-6.
3. Locate the holes in the jig that will fit your gauge length and mark size.
4. Select the ink colour to suit your specimen. See "Selecting the Colour of the Mark" on page 2-5.
5. Ensure that the marking jig is clean and has no residue of a previous ink colour that could cause cross contamination of your mark colour and therefore reduce contrast between mark and specimen.

Tip: *If you are continually using both black and white ink, it may be more convenient to purchase an additional marking jig.*

6. Ensure that your specimen is clean and grease free.
7. Lay your specimen down on a flat surface and position the jig over it so that the selected jig holes are located equidistantly about the centre line of the specimen.

Note: *Use the jig the correct way up, i.e. you can read the writing and the countersinks on the holes are towards the specimen.*

8. Apply the ink through the holes of the jig onto the specimen using the marking pens provided. Ensure that the ink is applied with an even density and that the marks made are as round as possible. See Figure 2-2.

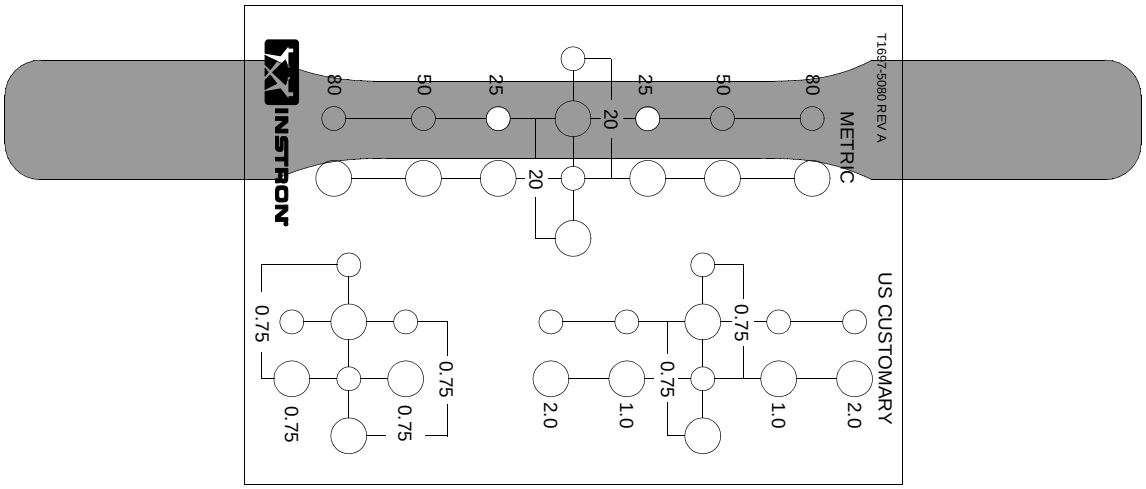

Figure 2-2. Marking a Specimen

Notes:

- *Keep the marking pen upright.*
- *Apply minimum pressure to the pen.*
- *Run the pen around the edge of the hole twice, then fill in the centre.*
- *Apply all the marks without disturbing the jig.*
- *Apply sufficient ink to meet the density requirements, without applying so much that the ink runs.*

When measuring axial and transverse marks with a 60 mm FOV you need 1mm dots to prevent slowing your PC response to an unacceptable level. Excessive sized spots will prevent measurement taking place. See "Applying 1mm Ink Dots" on page 2-12.

9. Carefully remove the jig by lifting vertically, taking care not to smudge the ink marks.
10. Clean the jig if required.

Note: *The jig material is Polycarbonate. Do not use abrasive cleaners or petroleum based solvents for cleaning the jig.*

11. When the ink is dry, inspect the marks, they should all be:
    - Round
    - Without any "bleeding" or "wicking" at the edge. See "Ink Dot "Bleeds" or "Wicks"" on page 2-13.

- Opaque
- Of an even density

Applying 1mm Ink Dots

1. Use the 2mm mark holes in the universal marking jig.
2. Apply the same method as described above, except:
   a. Do not run the pen around the hole.
   b. Press the pen tip gently, but firmly into the hole.

Note: *The pen tip is spring loaded. Do not "bottom out" the spring, or you will apply too much pressure and your dot will be too large.*

   c. Release the pressure on the pen and remove from the jig without any lateral movement.

Troubleshooting Ink Dots

Irregular Dot

Solutions:

- Apply more ink.
- Apply less ink.
- Degrease the specimen.

Ink Dot Smudges

Solutions:

- Apply less ink.
- Take more care when removing the marking jig.
- Do not accidentally touch the mark before the ink is dry.

Ink Dot “Bleeds” or “Wicks”

The surface of some specimens may cause the ink to “bleed”. This is commonest if the finish has been created by abrasives, e.g. graining of parent material used to create specimens. The wet ink is drawn, by capillary action, into the grooves caused by the abrasive.

The composition of some specimens may cause the ink to “wick”. This is commonest with woven materials. The wet ink is drawn, by capillary action, into the fibres of the specimen.

Bleeding and wicking give an indistinct edge to the mark so that the AVE software cannot lock on to the mark.

Solution:

- Use an alternative marking technique, e.g. Tape (see “Selecting the Mark Material” on page 2-4).

Ink Dot gets “Lost” During Testing

- The specimen has changed colour during test. Solution - see “Selecting the Colour of the Mark” on page 2-5.
- The mark has faded due to stretching. Solution - see “Selecting the Mark Material” on page 2-4.

- The ink has flaked off the specimen. Solution - check that the ink is compatible with the specimen. See “Selecting the Mark Material” on page 2-4.
- The mark has gone outside of the FOV. This is probably due to the specimen attaining a higher extension than expected. See “Field of View Considerations” on page 3-3.

The above incidents will cause the software to write an error message to the error log file. Review the error log file as described in your Bluehill documentation and refer to either the AVE Reference Manual or the on-line help for advice on how to cure the problem.

Applying Tape Dots

Instron recommend that you use the Target Applicator for applying tape dots for axial testing. See “Instron Specimen Marking Items” on page 2-8.

The Target Applicator applies circular dots of adhesive tape accurately onto the specimen for 10, 20, 25 and 50 mm (0.5, 1.0 and 2.0 inch) gauge length. See the documentation provided with the applicator for detailed instructions.

The Target Applicator applies the dots with an even pressure which prevents damage to the specimen and maintains an accurate gauge length during extension. It can be observed during testing of high extension materials using tape dots that the adhesive spreads evenly either side of the dot. Tape dots applied manually may not be adhered evenly, so that the gauge length in extension may be in error.

Troubleshooting Tape Dots

Tape Dot gets “Lost” During Testing

- Your specimen has changed colour during test. Solution - see “Selecting the Colour of the Mark” on page 2-5.
- The dot has dropped off the specimen. Solutions:
  - Check that the adhesive is compatible with the specimen. See “Selecting the Mark Material” on page 2-4.
  - Check that the tape is within its shelf life.
- The mark has gone outside of the FOV. This probably due to the specimen attaining a higher extension than expected. See “Field of View Considerations” on page 3-3.

The above incidents will cause the software to generate the error message **Error 106 Mark contrast too low**. The solution is to review your marking technique so as to prevent a recurrence.

Chapter 3
Application Specific Information

Outline

This section provides you with application specific information regarding materials testing with your AVE.

Grips

Instron offer an extensive range of standard grips that covers most test applications.

If you are not sure what grip type to use or are having difficulties during testing that appears to be grip related, please contact your local Instron service organisation.

Be aware that some grip shapes may cause shadowing in your application. See “Shadowing” on page 3-4.

Field of View

Field of View Considerations

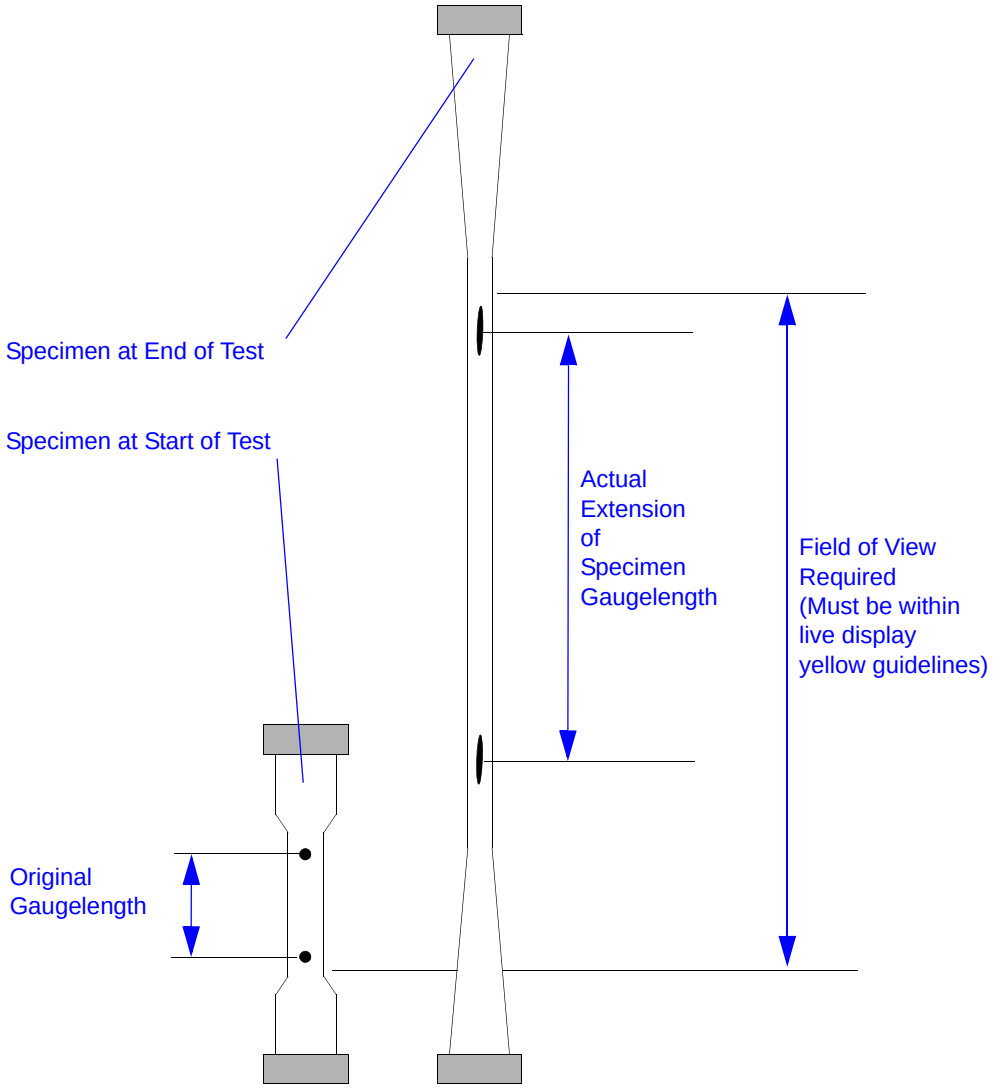

Figure 3-1. Field of View Considerations

Extension Testing Below the Moving Crosshead

Before you can set up your Video Extensometer system you need to know what the likely extension of your test specimen will be so that you can select the appropriate components. At this point it is important to remember that all material

specimens will extend outside of the gauge marks, so that the bottom mark moves up during the test, thus the field of view must encompass this movement (see Figure 3-2). In elastomeric specimens this extension is exaggerated and thus a wide FOV is required compared to the specimen gauge length.

Extension Testing Above the Moving Crosshead

The principle is the same as "Extension Testing Below the Moving Crosshead", but the direction of movement is reversed., i.e. the top mark moves down during the test.

Compression Testing Below the Moving Crosshead

The principle is the same as "Extension Testing Below the Moving Crosshead", but as compression testing moves the marks together, the whole thing is reversed, i.e. the bottom mark will move downwards during testing.

Compression Testing Above the Moving Crosshead

The principle is the same as "Extension Testing Above the Moving Crosshead", but as compression testing moves the marks together, the whole thing is reversed, i.e. the top mark will move upwards during testing.

Shadowing

Under certain test conditions, the grip may obscure the mark during testing. This can be at the start of a tension test or at the end of the test during compression testing. See Figure 3-2.

This condition is called shadowing and must be avoided. It is more obvious in tension testing, because the software algorithm cannot lock onto the mark that is obscured, so you will not be able to start your test.

The camera must be able to see complete marks (i.e. there must be a space between the mark and the grip or the mark and the shadow) at the start of a tension test or at the end of a compression test.

Note: *Due to the use of the polarizing filters, shiny surfaces such as grips are seen as black, so you may not be able to see the grip edge in the live display.*

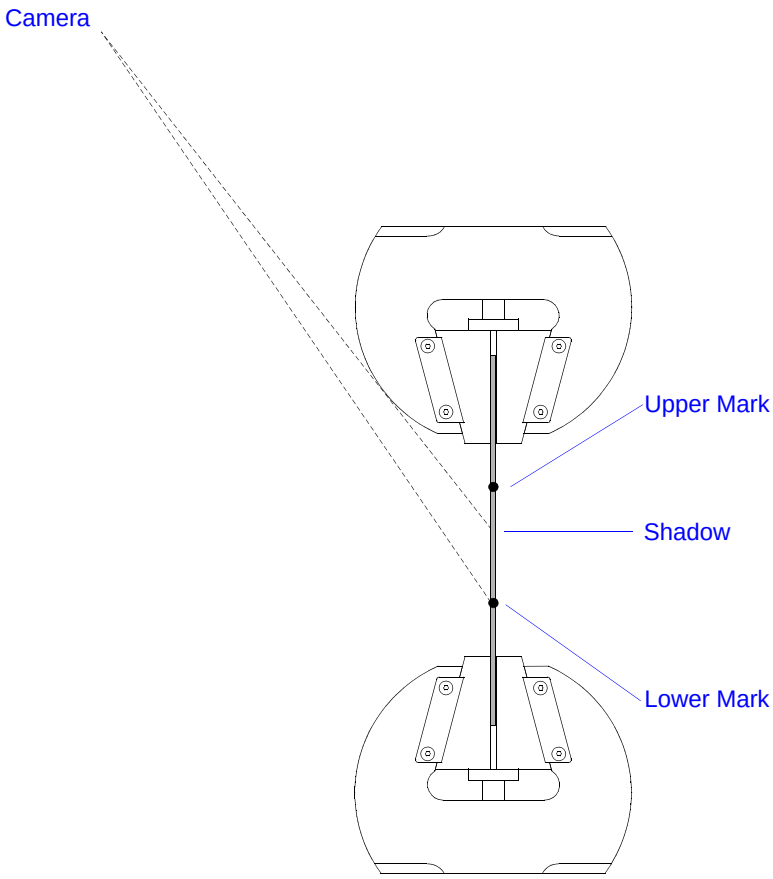

Figure 3-2. Shadowing

Elastomeric Specimens

About Elastomeric Specimens

As elastomers and rubber exhibit high extension to break, a video extensometer with a large field of view (FOV) is commonly used in order to capture the grip travel range in this kind of application.

When the specimen is small, for example, the specimen is tested under ISO 37, it involves some know-how to set-up the system properly which this section addresses.

Marking Elastomeric Specimens

The marking pens supplied with the extensometer do not produce good results for elastomeric specimens. This is because the mark spreads unevenly under high extension and becomes faint, so that the tracking of the mark is compromised.

In addition to the high extension, some elastomeric specimens are resistant to ink, e.g. silicon rubber which has a low coefficient of friction, or cast specimens covered in mould release agent.

Instron recommend that you use the tape dots for elastomeric specimens. See “Applying Tape Dots” on page 2-15.

Set-up Procedures

For the general set-up procedure, please refer to the documentation supplied with the video extensometer.

Field of View

The wide FOV needed for the high extensions expected in elastomeric specimens means that there are two particular considerations during set-up:

1. You need to conduct a ‘spanning’ calibration. The procedure for spanning calibration is discussed in detail in the Calibration Wizard section of the Preparation for Use chapter of the Operating Instructions.
2. You need to prevent “shadowing” at the start of the test. See “Shadowing” on page 3-4.

Calibration

As you will be using special grips, you will need to remove the upper grip and mount the calibration piece on the clevis attachment that matches your test machine load cell.

As elastomeric specimens tend to be small, you will, in addition, probably need to remove the lower grip in order to provide enough space to mount the calibration piece.

Wire, Cord and Yarn Specimens

About Wire, Cord and Yarn

The word ‘wire’ will be used throughout this section to mean wire, cord and yarn.

Contacting extensometers are not usually suited to wire testing because:

- The off-axis weight of the extensometer produces bending in the wire under test.
- When the wire breaks, it can damage the contacting extensometer.
- In some cases, the specimen will break because it cannot support the weight of the extensometer.
- The knife edges of the extensometer slip on hard wire.
- The knife edges of the extensometer damage wire made of soft material.
- Where the wire is multi-stranded, the specimen twists during extension.

Because the video extensometer is non-contacting, it does not suffer from the above problems and is, therefore, a logical choice for testing wire. Using the video extensometer for this kind of application involves some know-how. This chapter addresses the relevant points.

Notes: *Multi-stranded wire tends to twist during extension. See “Marking Multi-Stranded Wires” on page 3-9.*

Wire can also be braided. The additional implications of this are discussed in “Woven Specimens” on page 3-13.

Marking the Specimen

Marking Fine Wire

If the specimen is a fine wire, you can use small diameter (around 3 mm) expanded polystyrene spheres as marks. Expanded polystyrene spheres are usually used for packing purposes.

Slit the sphere with a scalpel down the center line to the middle and slip it around the wire. See Figure 3-3. Repeat with a second sphere and position the spheres to give you the gauge length you need.

The spheres are normally white. If another color is required, you will have to colour them.

An alternative for fine wires is a custom build target. Please contact Instron for further details.

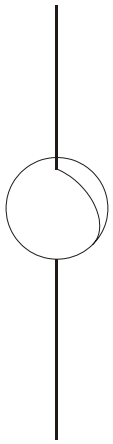

Figure 3-3. Mark on Fine Wire

Marking Larger Diameter Wires

- If the diameter of wire is big related to the FOV, a narrow strip of adhesive tape can be folded around the wire as a mark.

Marking Multi-Stranded Wires

- Multi-Stranded wires twist during extension. Do not use dots for marks because they will move out of the camera view during testing. Use lines as marks. See the methods described on this page.

Suggestions for Other Wire Marking Methods

Note: *The methods described below have not been validated with the AVE.*

- A stiff mixture of Magnesium Oxide and Glycerine can be used in place of an ink mark. This gives a white mark.
- Silicon grease on the wire can be used in place of an ink mark. This gives a black mark.
- A rubber ring around a wire, e.g. ‘O’ ring.

Set-up Procedures

For the general set-up procedure, please refer to the documentation supplied with the video extensometer.

As you will be using capstan grips, you will need to remove the upper grip and mount the calibration piece on the clevis attachment that matches your test machine load cell.

Warning

Wear protective glasses or use machine guards provided when testing wire, cord or yarn specimens.

When wire, cord or yarn specimens break, a lot of energy is released quickly. This can cause the tape dot, or custom mark to project from the test area at high velocity leading to possible injury.

Metal Specimens

About Metal Specimens

Traditionally testers of metal specimens have, for the most part, used contact extensometry as being the most practical option. Where video extensometry was applied, there were problems with reflection from the specimen and with the accuracy required due to the relatively low extension of metal specimens.

The development of the AVE features removes the reflection and accuracy problems, so that metal testing is now a simple method suitable for general tensile testing and R&N testing.

Marking Metal Specimens

General

Ink dots are recommended for most metal specimen marking. See “Applying Ink Dots” on page 2-9.

Ensure that metal specimens are degreased before testing.

Round Metal Specimens

For round metal specimens, the mark needs to conform to the surface and so ink is not a good choice as it is difficult to apply a good shaped mark. Use tape dots.

Hot Rolled Metal Specimens

Hot rolled metal specimens have oxide scale on the surface, which will flake off during extension or compression of the specimen. Removal of the scale may cause localised work hardening and therefore affect your test results.

Ink marks are still your first choice for this type of specimen, but be aware the mark could drop off with the flaking oxide. Contact Instron of you experience problems of this nature.

Set-up Procedures

If you are using grips other than flat faced, you will need to remove the upper grip and mount the calibration piece on the clevis attachment that matches your test machine load cell

For the general set-up procedure, please refer to the documentation supplied with the video extensometer. There are however, some special set-up requirements for metals testing.

Bluehill Metals Test Methods

Bluehill has special, pre-defined test methods for metals that comply with various ISO, ASTM and EN standards. Instron recommend that you set up a Bluehill metals test method that suits your test requirements.

Pre-Tension

To avoid erroneous test data, many metal specimens require a pre-tension. This removes any bends or other irregularities.

Typical values to use are 10 to 20% of the elastic limit of the metal.

Woven Specimens

About Woven Specimens

Woven specimens present a special case, either as:

- **flat,** e.g. Webbing, or
- **round**, e.g. braided cord

The materials used are often synthetic so that they are subject to attack from solvents or adhesives and the irregular surfaces do not lend themselves to good mark adhesion.

Marking Woven Specimens

Do not use ink for marking woven specimens, because the wet ink is drawn, by capillary action, into the fibres of the specimen. This phenomenon is known as “wicking”, which gives an indistinct edge to the mark so that the AVE software cannot lock on.

If the surface of the specimen is not too irregular, then tape dots are effective as marks. See “Applying Tape Dots” on page 2-15.

Where the specimen surface is rough, tape dots will only adhere to the high spots and may either drop off or not maintain a true centre position during a test. In these cases a custom target will need to be made. Please contact Instron for further details.

Lines can be effective marks for woven specimens, but all of the above comments also apply.

Suggestion for Marking Woven Specimens

Note: *The methods described below have not been validated with the AVE.*

- The mark is a flat metal disc, painted white one side with a pin protruding from the other side. Push the pin through the weave of the webbing and fix it by a clip on the side away from the painted disc.

Set-up Procedures

If you are using grips other than flat faced, you will need to remove the upper grip and mount the calibration piece on the clevis attachment that matches your test machine load cell.

For the general set-up procedure, please refer to the documentation supplied with the video extensometer. There are however, some special set-up requirements for woven specimen testing.

Pre-Tension

To avoid erroneous test data, most woven specimens require a pre-tension. This removes any stretch at the beginning of the test as the weave tightens. You need to be aware of this when setting up your FOV.

Typical values for pre-tension cannot be given, you will have to derive a value for your specimen empirically.

Warning

Wear protective glasses or use machine guards provided when testing woven specimens.

When woven specimens break, a lot of energy is released quickly. This can cause the tape dot, or custom mark to project from the test area at high velocity leading to possible injury.

Foil Specimens

The word foil also covers thin film plastic specimen.

About Foil Specimens

Foil specimens are, as their name suggests, very thin and therefore very weak. This presents specific problems for testing.

Marking Foil Specimens

General

In most cases, use ink marks.

Transparent Specimens

Use white marks.

Suggestions for Thin Film Plastic Specimens

The ink pens provided with the AVE are not suitable for marking thin film plastic specimens as they damage the specimen when attempting to make the mark.

Tape dots are not suitable for marking thin film plastic specimens as the as the target applicator damages the specimen when attempting to apply the mark

Note: *The methods described below have not been validated with the AVE.*

- Apply ink dots in a drop form using a metered syringe
- Use paint in a spray form and apply dots using a stencil.

Set-up Procedures

For the general set-up procedure, please refer to the documentation supplied with the video extensometer.

Be aware that shadowing may be an issue with pneumatic grips due to the piston housing obscuring the mark at the start of the test. See “Shadowing” on page 3-4.

As you will be using small grips for foil testing, you will need to remove the upper grip and mount the calibration piece on the clevis attachment that matches your test machine load cell.

Plastic Specimens

About Plastic Specimens

The term plastics, includes reinforced plastics

Generally, plastic specimens can be treated similar to metal specimens (see “Metal Specimens” on page 3-11), but there are specific recommendations as discussed below.

Marking Plastic Specimens

General

Ink dots are recommended for most plastic specimen marking. See “Applying Ink Dots” on page 2-9.

Some plastic specimens are cast and retain a coating of mould release agent. Ink is not a good choice here as the release agent rejects the ink, so that tape is a better choice.

PTFE specimens also reject ink, so that tape is a better choice.

Some plastic specimens change colour in extension. Select a mark colour that is always in contrast to the specimen colour (as seen by the camera).

Some plastics have high enough extension to be treated as elastomerics. See “Elastomeric Specimens” on page 3-6.

Check the compatibility of ink solvents or tape adhesives with your plastic specimen.

Round Plastic Specimens

For round plastic specimens, the mark needs to conform to the surface and so ink is not a good choice as it is difficult to apply a good shaped mark. Use tape dots.

High Modulus Composite Specimens

About High Modulus Composite Specimens

As High Modulus Composite specimens exhibit a low extension to failure, they can be treated similar to metal specimens (see “Metal Specimens” on page 3-11). Specific recommendations are discussed below.

Marking High Modulus Composite Specimens

Ink dots are recommended for most High Modulus Composite specimen marking. See “Applying Ink Dots” on page 2-9.

Some High Modulus Composite are resin filled woven material, giving a surface that causes ink marks to ‘bleed’. See “Ink Dot “Bleeds” or “Wicks”” on page 2-13. In these cases use tape dots, but be aware that where the specimen surface is rough, tape dots will only adhere to the high spots and may either drop off or not maintain a true centre position during a test.

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