**PURPOSE:** The test methods outlined in this document define equipment and techniques for measuring the stiffness of suspension components used in loudspeaker drivers. This document supercedes EIA RS-438 (ANSI C83.116-1976).

**SCOPE:** This document is intended to be used in conjunction with the applicable ALMA International document(s) in which it is referenced. These referencing document(s) may contain general information not included in this document, but which applies to this document, thus it is not recommended to use this document outside of its intended context. In the event of conflict, information in this document supercedes information in the referencing document(s).

**RESPONSIBILITY:** ALMA International Component Standards Sub-Committee

**RECORDS:** This document will be maintained and kept on file by ALMA International. Measurement results shall be maintained by the entity performing the measurement.

**RELATED DOCUMENTS:**
ALMA International Nomenclature Prints (NP's)
ALMA International Dimensioning and Tolerancing Guidelines (DG's)
ALMA International Measurement Test Method's (TM's)
EIA RS-438:1976 (ANSI C83.116-1976), Loudspeaker Spiders, Test for Measuring Stiffness.
True, Robert J., An Automated Method for Measuring Spider Compliance, AES Preprint 3744, (1993).
True, Robert J., A New Technique for Measuring Spider Compliance, SAE Technical Paper 940262, (1994).
Embree and Kimble, C Language Algorithms for Digital Signal Processing, Prentice Hall 1991.

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## 1 Introduction

The stiffness of the suspension affects the fundamental resonant frequency of the loudspeaker and provides the restorative force that controls the moving mass of the system. In many modern loudspeaker designs, the spider is the primary controlling suspension element.

The first revision of EIA RS-438 (ANSI C83.116-1976) was released in 1976 for measurement of spider stiffness. This measurement method provided a means for measuring the stiffness of a spider (typically at a single displacement) by hanging a known mass from a cap at the inner diameter. While this method serves a purpose in providing a quick estimation of spider stiffness using relatively inexpensive equipment, the measurement does not typically yield any information about the nonlinear behavior of the spider. Furthermore, this method may be prone to measurement error due to its highly manual nature. Finally, the method was restricted to the measurement of spider stiffness only.

This document is generalized to include the measurement of any loudspeaker suspension component (typically spiders and cone surrounds). To address the shortcomings of the hanging mass method, this document provides an additional computer controlled method that provides much more information about the component while minimizing the possibility of human error. However, the hanging mass method was not abandoned because there exists a long history of its use in the industry, particularly in the processing and fabrication of component raw materials, and the substantial cost of measuring equipment required by the new method may not be within the means of smaller driver and component manufacturers. Therefore, this document incorporates both methods and leaves the choice to the component supplier and/or customer.

This document is presented in two sections, method A and method B, with method A being the older technique and method B being the newer technique. The required test method(s) and test method order will be designated on the engineering drawing or other document by indicating the applicable sections after the TM number and a hyphen (e.g. TM-438-BA indicates that test method B should be performed and then test method A on the same part). Alternate tests may be indicated with a forward slash and applies only to the single sections on either side of the slash (e.g. TM-438-A/B indicates that either test method A or B may be used).

## 2 Definitions

2.1 Compliance — The reciprocal of stiffness.

2.2 Spider — The component in a loudspeaker driver attached to the voice coil that provides a portion of the driver axial restorative force and radially centers the moving assembly in the motor gap.

2.3 Stiffness - A measure of resistance to mechanical displacement, defined as the slope (secant through zero, not tangent at each point) of a force versus displacement curve. The stiffness can change with displacement.

2.4 Surround – The component in a loudspeaker driver attached to the diaphragm that provides a portion of the driver axial restorative force and seals the diaphragm to the frame.

## 3 Test Conditions

The test shall be conducted under equivalent ambient conditions for both methods A and B with the temperature being 20±8° C and the relative humidity being 50±10%.

## 4 Method A - Hanging Mass Technique

### 4.1 Test Equipment

Equipment shall consist of a fixture and associated elements to position the component, indicate location at rest, then indicate the new location after addition of the specified mass, positions being indicated by a reliable sensitive detector. Visual detection is discouraged unless aided by optical magnification. The standard arrangement shall be as shown in Figures 1 and 2. Any other arrangement shall meet the essential requirements of 4.2 and shall be compatible with procedures of 4.3.

### 4.2 Essential Requirements

4.2.1 Micrometer support arm A and component plate B shall be level and parallel. A may be hinged for easier access to the component. The micrometer shall be aligned normal to A.

4.2.2 Cap C shall have parallel top and component seating surfaces. It shall rest on the component neck J, where the neck points away from the base of the component. In the case of an inverted neck, where the neck points toward the base, the cap shall rest only on the innermost roll of the component, K, which points away from the base. The cylindrical alignment surface, I, shall be reasonably snugly fitted so as to center the component relative to the cap hook, L, but not so tight as to distort the component. Contact point D shall have a radius R of .1 to .4 mm at its end. It is preferably made of silver. The contact point shall be aligned so as to be centered over the cap hook and under the micrometer anvil. Mass of the cap and its hook shall be less than 10% of the displacement mass F. The cap shall be rigid so that it does not bend upon addition of the final displacement mass by more than 1% of the displacement distance after addition of the displacement mass. Bending shall be defined as the change in relative height of center and edge of the top of the cap.

4.2.3 Displacement mass, including the hook, shall be within 0.5% of its specified value. Preferred masses for all component measurements shall be 25, 50, 100 and 150 grams, with 50 g being the most common. If higher masses are desired, they shall be integer multiples of 50 g. Note that higher masses lead to higher displacements, which reduces the % measurement error, but increases the likelihood of entering the nonlinear region. The hook on the mass shall be fashioned and aligned so that the center of gravity of the mass will fall directly below the center of the cap.

4.2.4 Lead E shall be light, flexible and compliant so that it does not exert any significant force on the cap.

4.2.5 The flange of the component shall be clamped with a force of at least 10 times the displacement mass (force) to prevent slippage, which could affect readings. Clamp ring H or equivalent shall be used. Only clamping (no glue) shall be used and clamp inner diameter shall be specified to the nearest mm.

4.2.6 Detector G shall give indication of physical contact between micrometer and contact point with very light pressure. Contact pressure to give positive reading shall not be more than 1% of the force that the specified mass applies to the component. One suitable instrument is a sensitive, low current megohmmeter. Another is a transistorized code oscillator. Current through the contacts shall be low enough to prevent burning of the contacts. Voltage at exposed points shall not exceed 20 volts peak. A low current, low voltage detector as shown in Figure 3 gives an indication of contact from a light source.

4.3 Procedure

With fixture of Figure 1, the following procedure shall be used:

4.3.1 Test the cap for bending by setting it in a solid metal test ring which has an inside diameter equivalent to the inside diameter of the neck of the component to be tested, following the procedure of 4.3.2 through 4.3.4.

4.3.2 Position the component, clamping as specified. Insert the cap and bring the micrometer down until the detector indicates contact. Record micrometer reading.

4.3.3 Attach the specified mass to the hook. Bring micrometer down to contact and record micrometer reading within 5 seconds of the time of attachment. This is to minimize drift effects that may occur with heavy loading of soft components.

4.3.4 Calculate the difference between readings of 4.3.2 and 4.3.3. This difference is the "displacement" reading for the mass used.

4.3.5 During the preceding operations, observe the component for any abnormal distortion such as creasing, cocking, corrugation inversion, or neck deformation. These distortions could affect readings. If corrugation inversion or continued sinking of the component occurs, use of a lighter mass is suggested.

4.3.6 Contacts should be cleaned as necessary to ensure accurate measurements.

4.4 Reporting Format

The measurement results shall be reported as the displacement measured with the specified hanging mass. Preferably, metric units (mm) will be used. It should be recognized that dividing the mass converted to force by the displacement only yields a meaningful linear stiffness measurement when the component remains in a linear region of displacement. Since there is no way of verifying this for a given component by performing only one measurement, multiple displacements (hanging masses) should be measured.

4.5 GR&R (Gage Repeatability and Reproducibility)

0.051 mm, typically.

## 5 Method B - Automated Induced Displacement Technique

5.1 Test Equipment (see Figure 4)

5.1.1 Electronic force gauge with appropriate resolution, capacity and computer interface
5.1.2 Stepper motor system for controlled displacement of the force gauge
5.1.3 Mounting fixture for component and stepper motor
5.1.4 Mating clamps to match dimensions of the component and mounting fixture
5.1.5 Center plug with dimensions appropriate to inner diameter of component under test
5.1.6 Personal computer with interfaces to stepper motor and force gauge

Alternative equipment (e.g. servo motor drive force/tensile machine with built in displacement recording and force recording) can be used in place of the equipment listed in 5.1.1 and 5.1.2 as long as the resulting force versus displacement measurements are performed in an equivalent manner. In this case, certain steps in section 5.3 may or may not apply.

5.2 Essential Requirements

5.2.1 The mating clamp rings to be used shall be specified because the inner diameter will affect the results. It is recommended that the inner diameter of the clamp be equal to the largest roll outer diameter of the component rounded up to the nearest mm with a tolerance of ±0.05 mm. A clamping force of at least 10 times the maximum applied (measurement) force shall be applied.

5.2.2 The clamp rings shall be mounted horizontally so that the component is centered under the force gauge probe.

5.2.3 The dimensions of the center plug to be used for a given component shall be specified, as the plug shape will affect the results. It is recommended that the plug have a cylindrical lower portion with a diameter equal to the smallest component inner diameter with a tolerance of ±0.05 mm and height equal to at least twice the nominal component neck height. The upper portion, which will actually contact the component, should be conically shaped with 45° walls. The total mass of the plug should be no greater than 0.2 grams per mm of plug diameter.

5.2.4 The stepper motor system should be geared to achieve the desired step size when using one full step of the motor. The step must be sufficiently small to ensure accurate and repeatable results. A step size on the order of 0.1 mm works well for most components, but a larger step may be desirable if overall displacements of more than 4 or 5 mm need to be measured in a small amount of time. Whatever the step size used, it must be precisely known (to within 0.1%), as any error will accumulate with every step. This step can be determined by measuring a long excursion created by taking many steps. For example, if 100 steps yields 10mm+/-0.1 mm of excursion, then the steps size is 0.1 mm/-0.1%. Since stepper motors yield step sizes based on the spacing of their magnets, the step size never changes and is very consistent from step to step for full steps. (Half steps are not encouraged because odd and even numbered step sizes tend to differ.)

5.2.5 The fixture and motor drive system shall be sturdy enough as to not flex at the maximum applied (measurement) force.

5.2.6 The force gage should have a resolution of at least 1 mN and an accuracy of at least +/- 1% of full scale. The capacity should be sufficient to measure the maximum force generated by any component at the required peak excursion. Typically, 50 N is sufficient, but in some extreme cases a higher capacity may be required.

5.2.7 The time allotted for collecting the force data at each resulting displacement should be as short as possible without affecting the repeatability of the measurements. Ideally the force gage will update continuously so only a few tenths of a second will be required for the reading to settle before it is recorded. If a force gage takes longer than 0.5 seconds to update, it may not be suitable, as a certain amount of creep of the component material will result during this time.

5.3 Procedure

5.3.1 Place the component in its specified mated clamp assembly (see Figure 4).

5.3.2 Insert the specified center plug.

5.3.3 Lower the force gauge until the probe contacts the center plug. Adjust the force gauge position until the force gauge reads between 5 and 10 grams. This will ensure that no readings are taken on the order of the force gauge accuracy. This amount of force is rarely large enough to drive the component into nonlinear operation. The corresponding position will serve as a temporary zero reference displacement point.

5.3.4 Move the force gage one additional step in the direction in which the measurement will be performed in order to ensure any backlash in the stepper motor system is accounted for.

5.3.5 Lift the force gauge for 1-2 seconds, then move the force gauge downward in equidistant steps and record the reactionary force at each step. Continue recording the force at each step until the maximum specified displacement or force is reached.

5.3.6 Subtract the inward probe displacement from total induced displacement at each step. Within the linear range of the gage, the inward displacement will be proportional to a constant that is easily determined through calibration measurements.

5.3.7 If the units read by the force gage are not those desired for reporting, then scale the readings as necessary

5.3.8 Add the weight of the plug to each force gauge reading. If the force gauge reads in units of mass, multiply the measured value by the gravitational constant at the measurement location and any required conversion factors to obtain the force in N.

5.3.9 Apply a curve fit to the force versus displacement data. This will increase the resolution and accuracy of the measurement while making it easier to interpolate the results at practical intervals (e.g. 0.1 mm.) A least squares polynomial curve fit with a number of terms just sufficient to accurately fit the data works well. The lowest order polynomial that provides a R-squared ($R^2$) > 0.95 should be used. To achieve optimal smoothing, the order of the polynomial should be small compared to the total number of points being fit. Evaluate the slope (m) and force intercept (b) by evaluating the force (F) versus displacement (x) curve fit at over the first few points up to 0.75 mm of displacement (try to keep most suspension components in the linear range) and fit a straight line F = mx+b between them. Then calculate the displacement offset (d): d = -b/m.

5.3.10 Take the original force versus displacement data and subtract d (which is negative) from each displacement. This will account for the offset created when the first force measurement was considered to be at zero displacement. Note: the first force measurement is now shifted to indicate the true starting point of the measurement that was -d.

5.3.11 Apply the same curve fit as in 5.3.9 to the shifted data. Now the data is ready to be interpolated at desired intervals and stored, plotted, or reported.

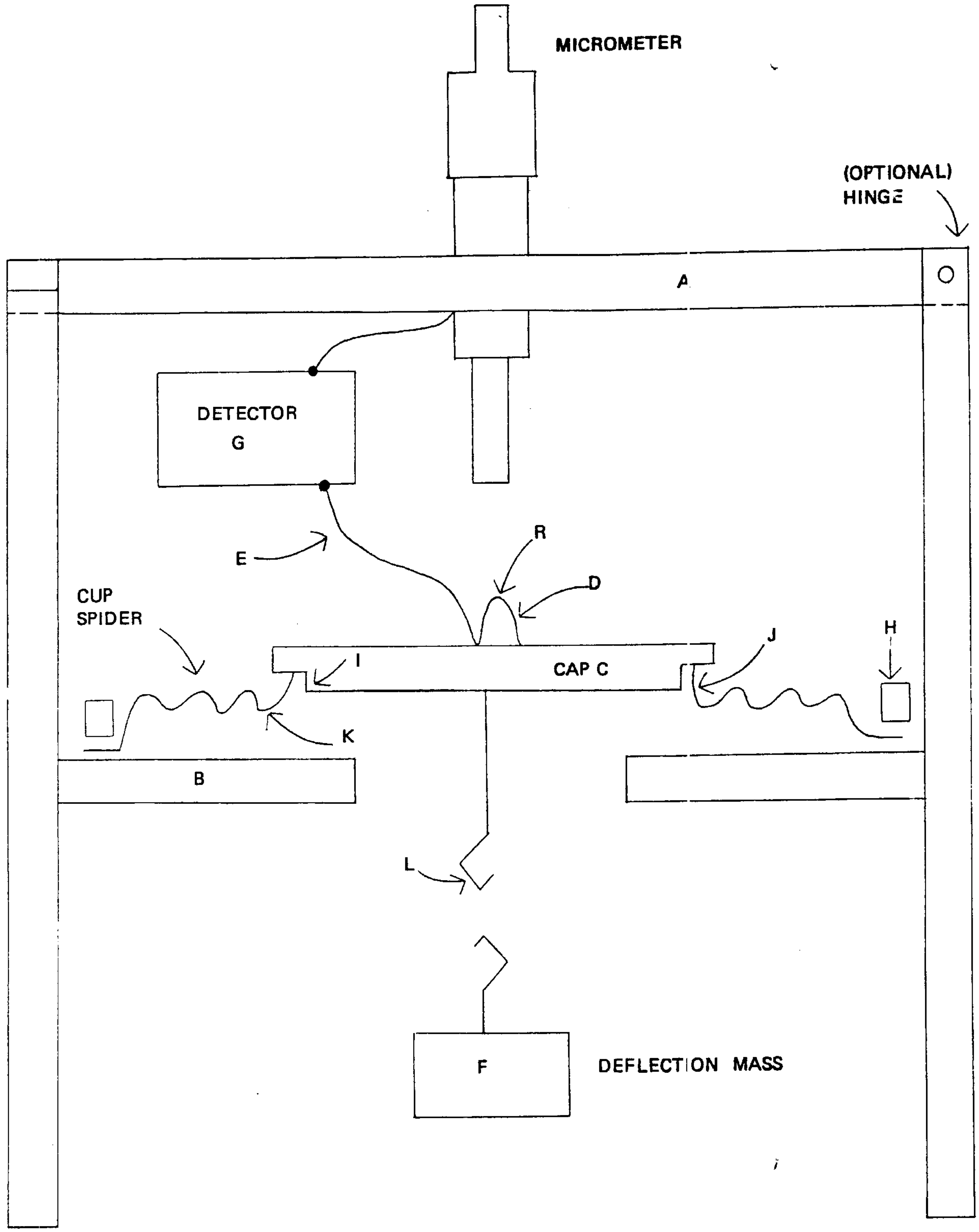
5.4 <u>Reporting Format</u>

5.4.1 If the data is desired in force versus displacement format, then interpolate the curve fit data at 0.1 mm intervals and report or plot as such. The units of displacement shall be mm and the units of force shall be N.

5.4.2 If the data is desired in stiffness versus displacement format, then divide the results of 5.4.1 by the displacement at 0.1 mm intervals and report or plot as such. The units of displacement shall be mm and the units of stiffness shall be N/mm.

## Revision History

| Rev Level | Description of Change | Prepared/ Changed By/ Date | Approved By/ Date |
|---|---|---|---|
| DRAFT | Create document | Bob True<br>Brian Sterling<br>2/15/05 | -- |
| 1/19/07 | Add GRR for Method A<br>Release document | Brian Sterling<br>1/5/07 | ALMA<br>Committee<br>1/7/07 |



MICROMETER
(OPTIONAL)
HINGE
A
DETECTOR
G
E
R
D
CUP
SPIDER
I
CAP C
J
H
K
B
L
F
DEFLECTION MASS


FIGURE 1

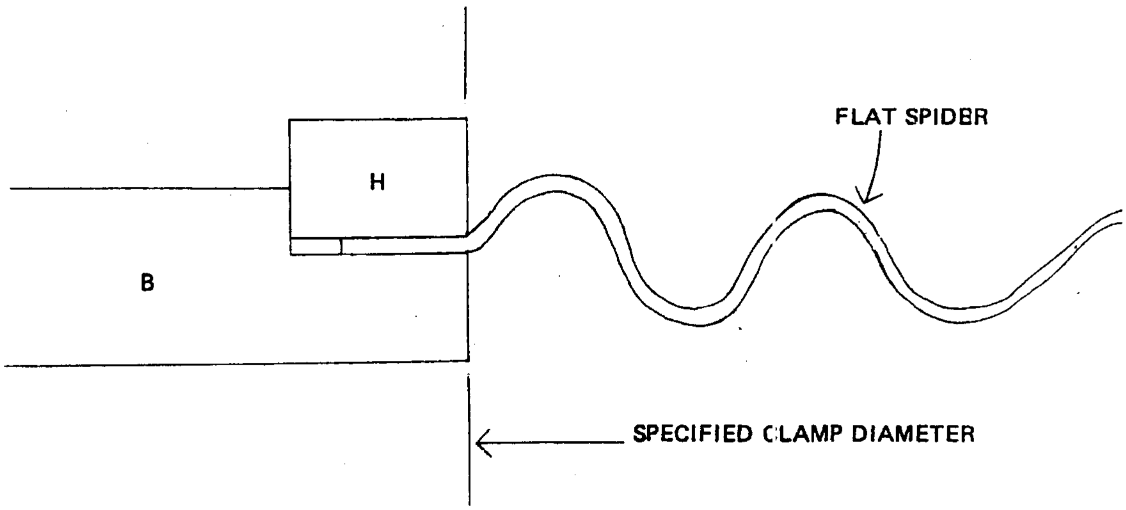



FIGURE 2

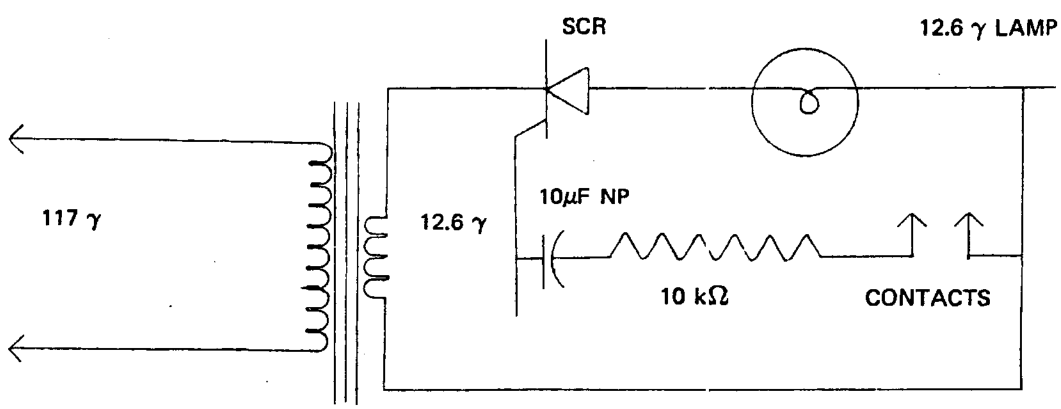



FIGURE 3

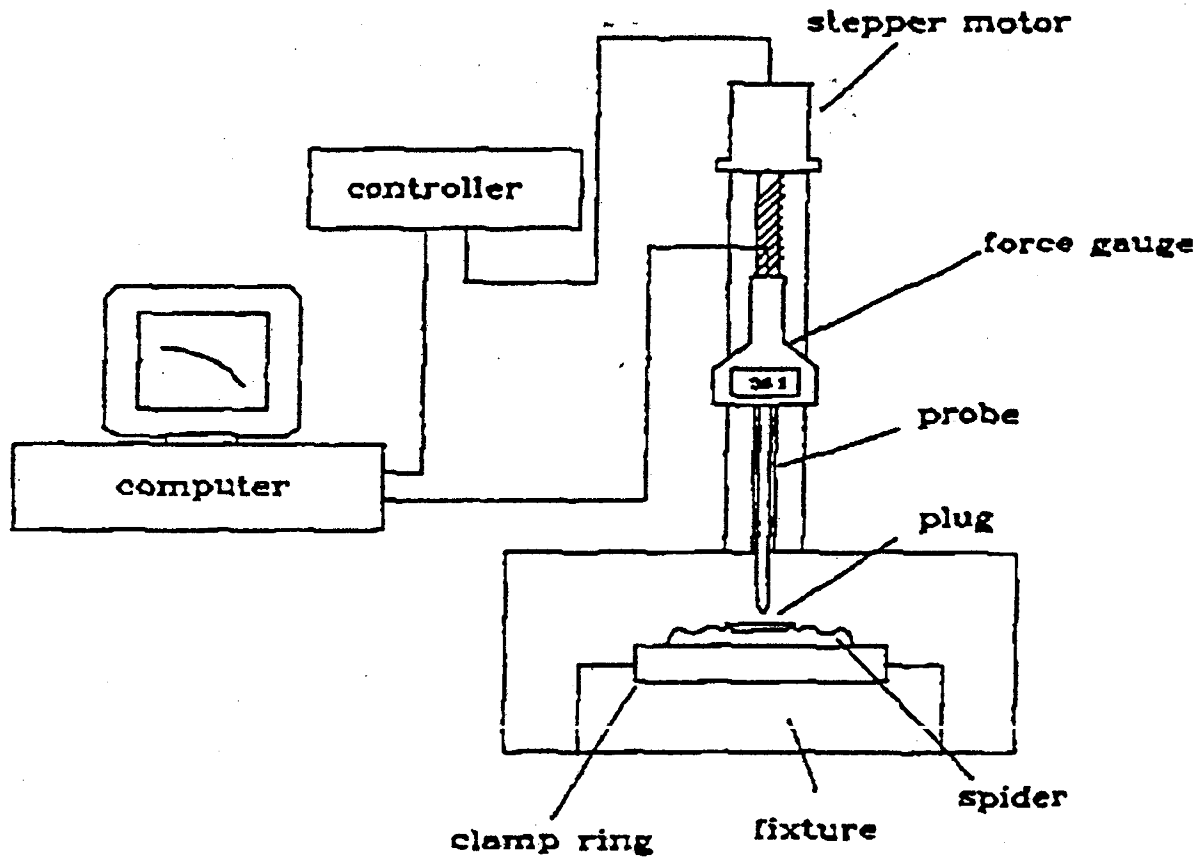



Figure 4 Apparatus for Induced Displacement Spider Compliance Measurement.