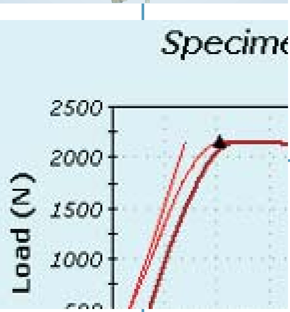
7 TIPS FOR MATERIALS TESTING



INSTRON®

Introduction

Static materials test system (electromechanical drive)

Static materials test system (hydraulically powered)

Characterizing material properties is a primary objective for quality control and R&D laboratories. Yet, choosing the right test is not always obvious. There are many different types of static and dynamic tests, including: tensile, compression, shear flexure and fatigue/fracture.

The following should be considered when choosing the correct testing system:

- **Test Type:** tensile, compression, flexure, torsion, shear, reverse-stress (torsion and compression)
- **Testing Specimens:** configuration, size, shape and material
- **Ultimate Test Loads:** the highest expected load expressed in pounds, newtons or kilograms
- **Ultimate Strain-Extension/Compression:** the highest expected elongation expressed as a percentage of initial gauge length
- **Strain Measurements:** extensometer gauge length, percentage of travel, other requirements

This pamphlet aims to offer tips on how to choose the right testing machine based on these and other considerations.

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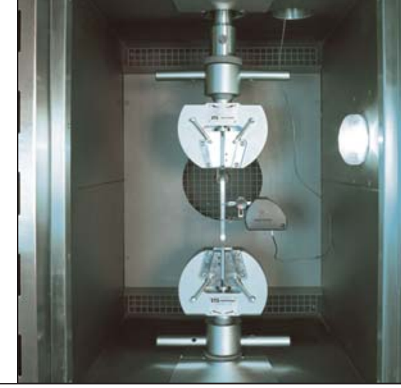
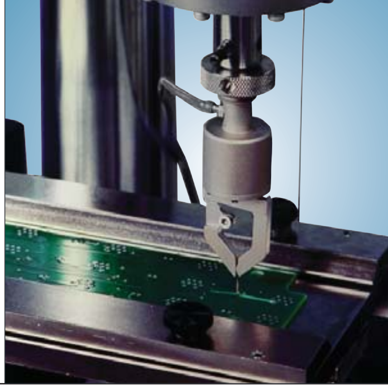
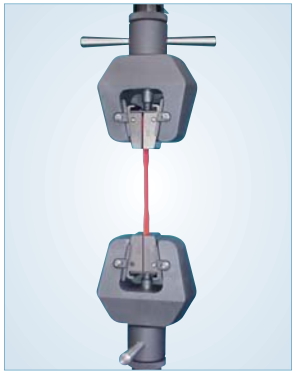


Dynamic test system

Impact test system

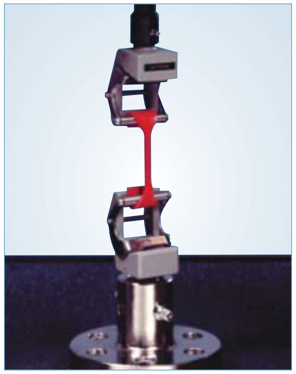
Tip 1: Grip Selection





Mechanical wedge action grip

Successful gripping solutions require the specimen to be held in a way that prevents slippage and jaw breaks and ensures axiality of the applied force. In some cases the gripping requirements are very specific and a purpose-designed grip or fixture is necessary to meet a particular testing standard. However, in most cases, you can use general purpose accessories. General purpose grips and fixtures have the advantage of being able to grip a wide variety of specimen types and materials using a range of options such as different jaw faces, alignment fixtures, etc.



Self-tightening roller grip

Specimen Gripping Solutions

Two of the most common problems operators face are specimen slippage and jaw breaks. Slippage occurs most frequently when using mechanical or screw action grips with flat faces. When selecting grip faces, the surface area should be large enough to cover the tab (for dumbbell samples) or, for a parallel sample, as much of the surface area as possible. With any grip, ensure that the specimen end is gripped by at least 75% of the available jaw face length, otherwise gripping efficiency is reduced and in some cases, the jaw face can be damaged.

The important thing to remember if you experience gripping problems is to experiment. How you arrive at the end result is incidental.

Jaw breaks usually occur when the sample inside the grips is damaged by too much clamping force or by serrated faces biting too deep. Below are tips to reduce jaw breaks:

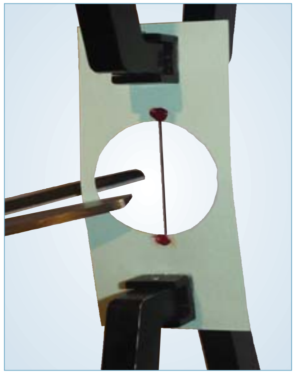
- **Screw Action Grips:** The operator may be using too much force when tightening onto the sample; use a torque wrench or pneumatic grips.
- **Pneumatic Grips:** Drop the pressure, but not to the point where you get slippage.
- **Serrated Faces:** Change to faces that have more serrations per inch (less bite) or cover with masking tape or comparable material (this will soften the bite and prevent damage to the sample).

Testing Monofilaments and Single Fibers

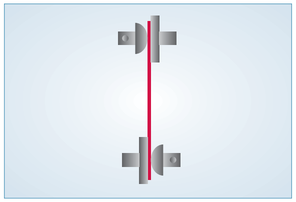
A single fiber, or monofilament, may be affixed to an aperture card. The gauge length of the specimen is the height of the aperture. The card is cut on the slant on either side of the specimen after it has been mounted in the test instrument.

Hints for Reliable Gripping

- Periodically inspect the grips for defects such as cracks or leaks in hoses.
- Periodically verify pressure gauges are accurately registering air or oil pressure to the gripping system.
- Replace jaw faces when the surfaces become worn, damaged or contaminated.
- Do not use more gripping force than necessary to provide reliable, slip-free gripping.
- Old grips don't necessarily work with new materials or specimens.
  - ~ You may find that special grips or different jaw face surfaces are needed.
  - ~ You can try a variety of things to modify existing gripping methods including emery cloth, sticky tape, etc.



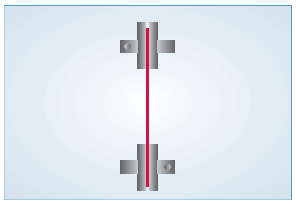
Tensile test of single fibers



Line contact grip face

Using Line Contact Grip Faces

Paper and other sheet materials are best gripped in line contact grip faces, where the gauge length is between the center of the two line contacts.



Plain ground grip face

Testing Sheet Samples

Plain ground (no serrations) grip faces can be used to grip film, foil and other sheet materials. Sheet metal specimens should be gripped with serrated faces, where the diamond serrations will bite into the specimen to prevent slippage.

Anti-seize lubricant

Looking After Your Grips

Any successful gripping solution can be adversely affected by poor maintenance. Many common gripping techniques rely on friction or local surface deformation of the specimen to function. If the gripping surfaces become worn or contaminated, gripping efficiency is compromised. Ultimately, this causes slippage of the specimen and an invalid test. In order to ensure proper grip function, regularly clean your grips and lubricate moving parts with the correct grades of lubricant as advertised by the manufacturer.

Tip 2: Load Cell Selection

Characteristics of Load Cell

Load cells measure the force experienced by the specimen and output an electrical signal that is used by the electronics to precisely monitor, report or control the force. In order to choose a proper load cell for your test, the following characteristics of load cells should be considered:

- Capacity
- Accuracy
- Repeatability
- Off-set loading error
- Non-linearity
- Compensated temperature range
- Temperature effect on zero and sensitivity
- Life time (especially for dynamic cells)
- Overload capacity
- Off-axis stiffness

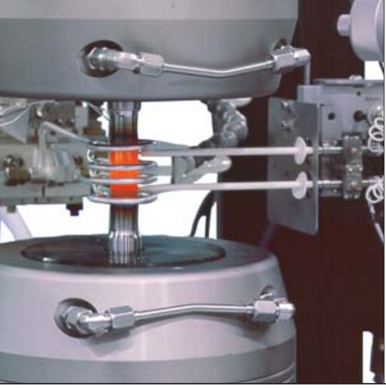
Additionally, consider the availability of self-identification* to prevent human errors when setting up for a test. It is important to note that most transducer manufacturers specify linearity of their load cells as a percentage of the full-rated output (% F.R.O.). This can be misleading when using lower ranges (say 1% of capacity). A load cell rated at 0.05% F.R.O. produces a reading error of 5% at 1:100th of Full Scale.

Hints for Testing

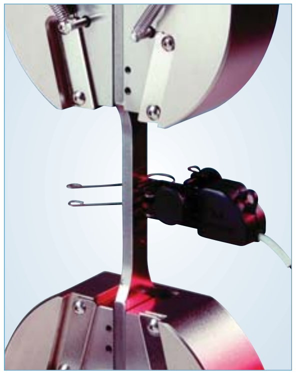
- Always clamp specimens in the grip not attached to the load cell first (usually upper grip).
- Warm up a load cell a minimum of 15 minutes.
- Once a specimen is clamped in place, don't change the balance or crosshead position controls.
- Never put a load cell in an oven.
- Use the Load Protect function to protect specimens from damage.
- If testing at less than 2% of capacity, think about changing to a lower capacity load cell.

Dynacell™ for dynamic tests

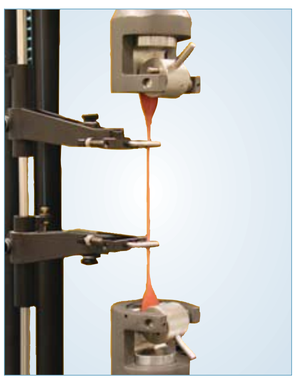
*Note: Self-identification is an automatic feature that recognizes which load cell is connected and determines whether it has been calibrated. This feature prevents operators from using a machine with an incorrect setup.



Tip 3: Extensometry Selection



Clip-on extensometer



Long travel extensometer

Necessity of Extensometry

Any mechanical system subjected to a force will deform, however slightly. This applies equally to material testing systems. The load frame, load cell and grips of your system are not infinitely stiff and will deform slightly as force is applied to the specimen. This deformation is called compliance and can lead to significant errors in test results especially for high capacity test with small travel requirements.

Most material test systems measure crosshead or actuator displacement and this can be used as a measure of specimen deformation. However, the displacement output recorded by the system is actually the sum of the system compliance and the specimen deformation.

In many applications, such as tensile testing of plastics and elastomers, the system compliance is often very small when compared to the specimen deformation and the error can be ignored.

Where very precise measurements of specimen deformation are required, the use of extensometers avoids system compliance errors completely.

Extensometer Types

There are two main types of extensometers:

- **Contact Extensometers:** clip-on, long travel, high-temperature, etc.
- **Non-Contact Extensometers:** laser, video

While providing accurate measurement in many applications, contacting extensometers can have an adverse effect on test results. Non-contacting extensometry offers many benefits over traditional contacting devices, including:

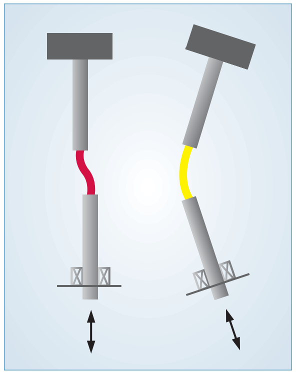
- No influence on the test specimen
- No problems with knife-edge slip
- No errors due to inertia of moving parts
- No moving parts eliminate errors due to wear
- No possibility of damage due to energy release at failure
- Can be used with environmental chambers over a wider temperature range

Hints for Clip-On Extensometers

- Be sure the extensometer is mounted straight and on-center of specimen.
- Attach your extensometer properly to get best test results and avoid slippage errors.
- Use proper clip sizes for attaching to specimens.

Advanced Video Extensometer (AVE)

Tip 4:
Optimizing Specimen Alignment



S-Type and C-Type Bending

Why is Good Alignment Necessary?

The easiest way to put unwanted stresses into a test piece is to bend it. The easiest way to bend it is to misalign it initially and/or load it non-uniformly by:

- **S-Type Bending:** concentricity offset application
- **C-Type Bending:** angular offset application

Many standards (such as ASTM, ISO, etc.) specify quality of testing in terms of % bending, e.g. $<$ 5% of nominal strain or of strain amplitude.

Optimizing Specimen Alignment

As a general rule, ensure that the axis of force application runs through the centerline of the specimen. Off-axis loading of the specimen can lead to various problems:

- Specimen bending, which results in poor modulus values when using single-sided extensometers.
- Specimen buckling in compression and through-zero tests.
- Offset loading of the load cell, leading to errors in output or in extreme cases load cell damage.
- Non-uniform stress conditions within the material, making it behave differently.
- Edge effects caused by high local stress at the specimen edges.
- Scattered test results if the misalignment is random.

There are several ways to improve the alignment of the specimen. Some applications require the use of additional fixturing to obtain the best possible alignment, where others may simply require more attention by the operator to ensure the specimen is loaded accurately and consistently.

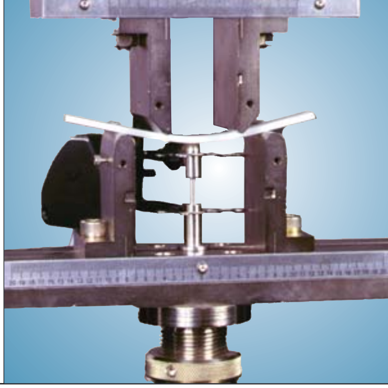
Flexible or universal couplings can be employed to allow the grip to align itself with a slightly bent specimen. Some types of grips employ two universal couplings, one at the top and one at the bottom.

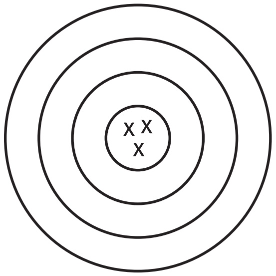
A variety of grips and fixtures feature specimen stops that allow the specimen to be accurately and repeatably located.

Spherically-seated compression platen for rock test

Specimen centering device

Tip 5: Accuracy, Resolution and Precision





Accuracy

In order to identify a required test and define the requirements for testing machines, it is important to understand the difference between accuracy, precision and resolution.

Accuracy

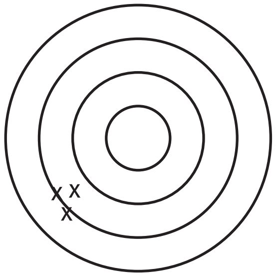
Accuracy describes how close a measurement is to the actual value. It is important to note how the accuracy of a device or instrument is stated. It is usually presented in one of two forms - percent of full scale or percent of reading. Percent of full scale is often shown as %FS. This is a fixed error and the error as a percent of reading becomes much greater at lower forces. For example, device X has a 200 lbf capacity and an accuracy of 0.3%FS (typical of force gauges). This means that at 20 lbf, the error will be 0.3%FS, or 0.6 lbf, which is 3% of the reading (this is outside of the ASTM requirement that measurements to E 4 be within 1% of reading).

90° constant angle peel fixture

Percent of reading is often shown as %RO (percent of readout). Instruments that specify accuracy as a %RO typically have a wider range of use, since this is a more difficult specification to meet. For example, device X has a 200 lbf capacity and an accuracy of 1% RO (more typical of testing machines). This means that at 20 lbf the error will be 1% of the reading, or 0.2 lbf (within ASTM E 4 requirements).

Precision

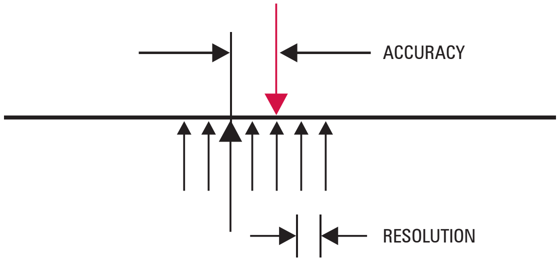
Precision (or repeatability) means that you can hit the same point time and again within certain error limits. But, as the target illustrates, you can be precise without being accurate. Precision alone does not ensure accuracy; accuracy is best achieved with both precision and calibration. This means that you not only repeat time and again within prescribed error limits, but also that you hit what you are aiming for.



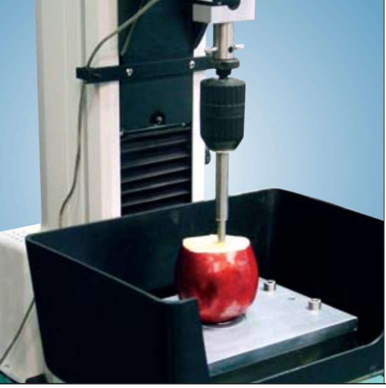
Precision

Resolution

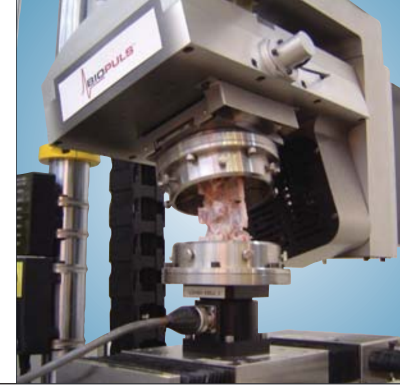
Resolution describes the smallest increment of measure that a device can discern. For example, a 200 lbf device with a 0.01% resolution can make measurements in increments no smaller than 0.2 lbf.



Tip 5: Accuracy, Resolution and Precision



Tip 6: Data Rate and Bandwidth



Tension test of spring

Ultimate strength of tubing material

Faster is not always better and here's why: The data acquisition rate of a computer or data acquisition system is the rate at which raw data samples are taken. This rate needs to be selected based on the speed at which the incoming signal is changing. If the incoming signal is not changing quickly, then higher data rates only produce excessive data, large files and wasted disk space.

There are three main variables to consider in the data rate discussion:

- The actual signal being measured
- The bandwidth of the signal conditioner (filtering)
- The data acquisition rate

Actual Signal

One of the most critical aspects of proper measurement is to understand the rate at which things occur during a test. For example, when testing composites, there are short, sharp peaks (or signals); but tensile tests on plastics typically show no high frequency signals.

Bandwidth

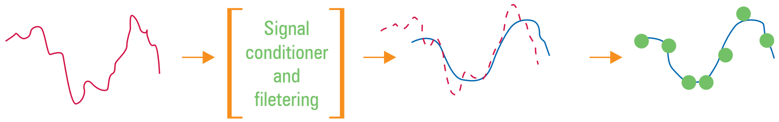
In order to properly catch these actual events, one needs signal conditioning with the right frequency bandwidth. Bandwidth can be loosely defined as the frequency above which signal changes are not measured - they are filtered out and flattened. For example, it is not possible to measure 100 Hz peaks with a 10 Hz signal conditioner; the peaks will be smoothed out and become invisible. Most electromechanical testing machines have fixed, low bandwidth signal conditioners, generally on the order of 3 Hz to 5 Hz.

Data Acquisition Rate

The ideal data acquisition rate is a function of the signal conditioning bandwidth, which in turn should be matched to the rate of change of the actual event. A rule of thumb is that a data rate more than 10 times the Signal Conditioning Unit (SCU) bandwidth produces little more than wasted disk space, because the same data is being sampled over and over.

For a complete review of data rate, signal conditioning, noise filtering and how it affects mechanical testing results, consult ASTM Standard Guide E 1942.

Performing tests with appropriate data rate and bandwidth is critical in obtaining accurate and meaningful data.



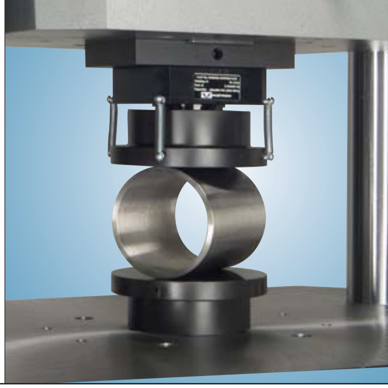
Ultimate strength of tubing material

Hints for Data Collection

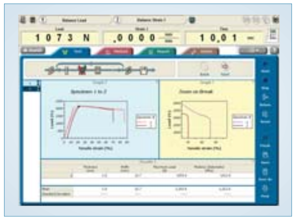
On Data Rate
(often defined by the user):
too high = unnecessary amounts of data points
too low = missed peaks and potentially misleading results

On Bandwidth
(often fixed in machine):
too high = noisy signal and loss of resolution
too low = filtered peaks and potentially misleading results

Tip 6: Data Rate and Bandwidth



Tip 7:
Software Function and Performance



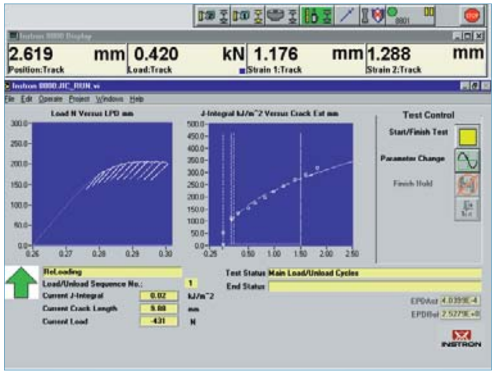
Runtime screen for prompted test

User-programmed test sequence

Software plays an important role in controlling the testing machine, acquiring and analyzing data and reporting results. A user-friendly interface, easy setup and powerful functions contribute to increased testing productivity. In order to ensure that the function and performance of testing software will meet your requirements, check the following points:

Basic

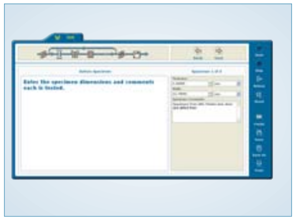
- **Installation:** This is configured for easy installation and removal by the user.
- **Interface:** It's designed to be intuitive, as well as easy to use.
- **Copy and Paste Capability:** These help you copy result tables and graphs from the software and paste into third-party software packages like MS Word, Excel or PowerPoint.



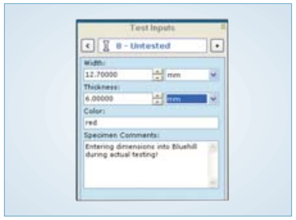
J-Integral fracture toughness

Test Preparation, Control, Operation

- **Automatic Identification, Calibration, Balancing for Transducer:** These will support preparation of testing and greatly reduce the chance of operator error, calibration errors or bad data, etc.
- **Input Channel:** Many test systems are limited to two channels (load and extension). Additional channels, or optional channels, are important for future capability such as the addition of strain.
- **Test Sequence:** Configured and defined test sequence ensures that operators do the same tests and reduces operating errors.
- **Test Method Creation:** Customizable method templates for standards, such as ASTM, ISO, DIN, JIS, EN, etc. are available.
- **Parameter Settings:** Easy to save and recall test parameters, including specimen data.
- **Raw Data:** Availability to view raw data during the test will help operators detect errors in attaching specimens, extensometers, etc.
- **Compliance Correction:** Compliance correction is available in case the use of extensometers is inconvenient (see Tip-3). Compliance correction is critical for testing strong/stiff materials without extensometry.

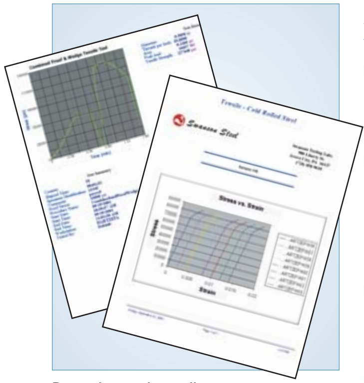


Prompted test sequence



Specimen data saved as test parameters

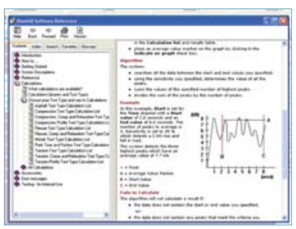
Tip 7: Software Function and Performance



Reporting options allow users to share detailed test results with ease

Analysis, Results and Reports

- **Graph:** Appropriate graphs and tables with user definable graphics, labels and auto scaling.
- **Analysis:** Required calculations (ie: breaking stress, offset yield) and the ability to edit and create user-defined calculations are available.
- **Report Generation:** Reports are generated in many formats, such as PDF, MS Word, HTML, etc.
- **Data Export:** This is compatible with third-party application software, such as MS Word, Excel, etc.

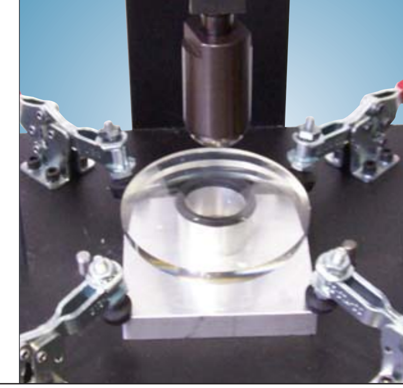


Reference help for peel testing

Security, Safety, Help

- **Security:** Availability of user management and password protection.
- **Upgrades:** Modular-designed structure enables easy addition of functions.
- **Online Help:** Availability of operating instructions, testing tips and terminologies, etc.
- **Safety:** User defined limits and end of test criteria.

Notes



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