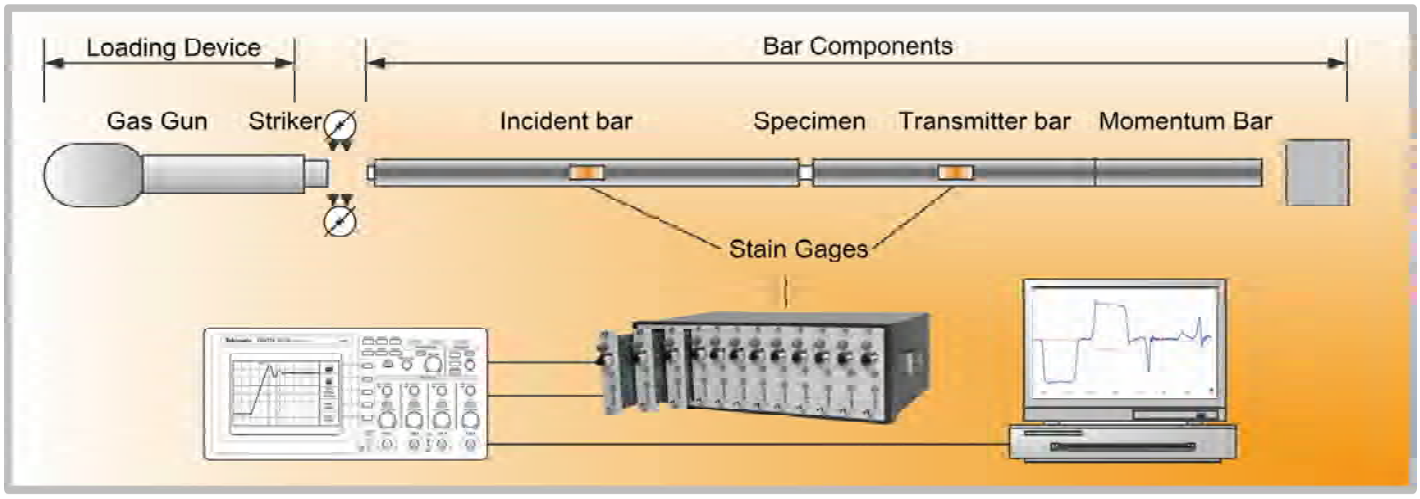
Split Hopkinson Bar
High Strain Rata Material Testing

Materials undergo high strain rates deformation in various applications, e.g. accidental events such as explosions and penetrations, and engineering applications such as crash worthiness of vehicles, bullet proof armors, impact resistant pressure vessel and shipping cask for transport of nuclear materials. In addition to this, forming processes like extrusion, rolling and high speed machining can also result in high strain rate deformation. For the optimal design and safety analysis of components seeing high strain rates of loading the constitutive behavior of materials at high strain rates is required.

Dynamic testing of material is becoming more important due to the need for more optimized crashworthiness and impact analysis. Positive strain rate sensitivity, i.e. the strength increases with strain rate, offers a potential for improved energy absorption during a crash event. The load can be an instant load wave used for very high strain rate. The machine will also have the proper measurement systems to measure and record the important parameters, such as strain, displacement and load.

Split Hopkinson Bar system, Single Bar (SB) system is the systems commonly used.
The systems has been developed by Adavnce Instrument Inc. in recent years to meet the increasing demand for dynamic testing.

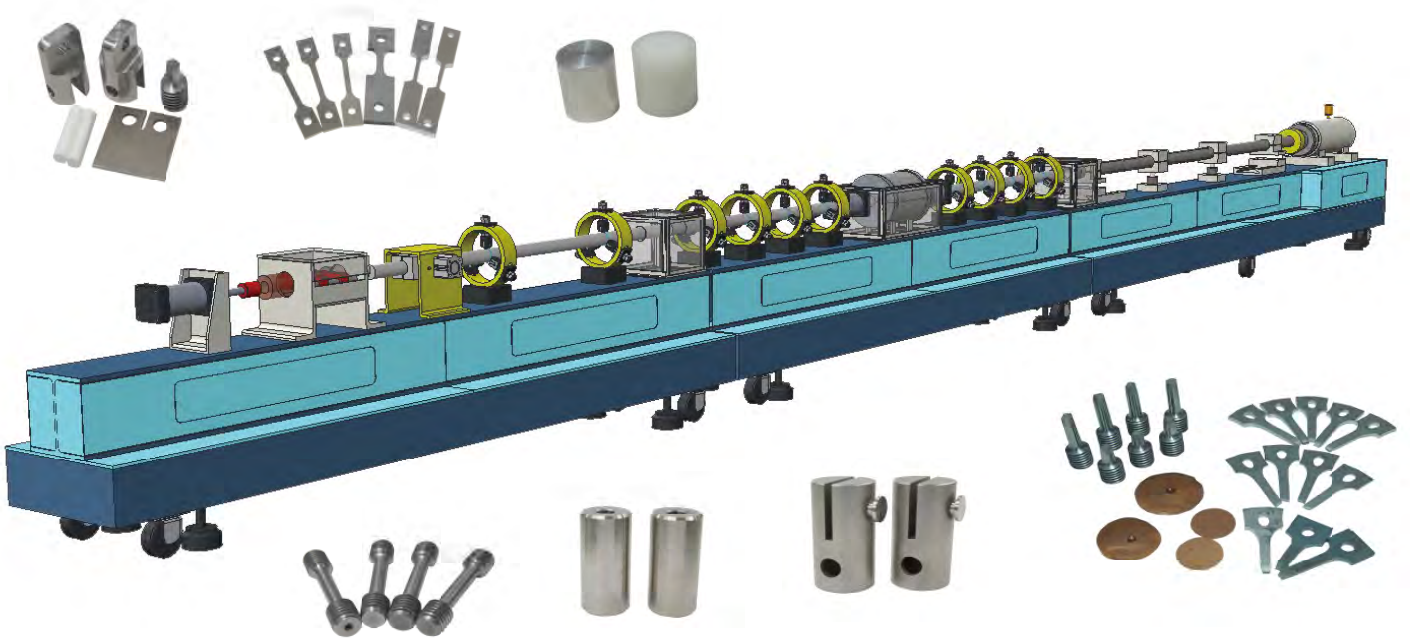


Principle of Split-Hopkinson Pressure Bar

Split-Hopkinson bar (SHB) works on the principle of one dimensional wave propagation. Its main components are a gas gun, a striker bar, an incident bar and a transmission bar . The striker bar sits in the barrel at the gas gun chamber. The incident bar, transmission bar and striker bar are all made of same material and same cross-section area. At all times during the test the striker, incident and transmission bar should remain elastic. The sample to be tested is sandwiched between the incident and transmission bar. The striker bar is propelled by gas pressure towards the incident bar.

On impact, an elastic compression wave propagates down the incident bar toward the sample. On reaching the sample, repeated wave propagation within it deforms it plastically. Part of the wave goes through to the transmission bar (transmitted pulse) and part is reflected back into the incident bar (reflected pulse), each of which is picked up by the strain gauges mounted on the corresponding bars. Strain gauges on each bar are mounted to the axial strain. Elastic strain generated in incident and transmission bar are used to calculate the stress-strain in the sample.

SHPB SHTB Test Apparatus



Advance Instrument Inc's designs a number of conceptual for SHPB were thought of and the optimized design was worked out. The precision tolerance, straightness in bars and design and proper functioning of pneumatic gun were met. This setup has been used extensively to study the high strain rate material behavior.

The system consists of the dynamic loading units, data acquisition and control system and spare parts & tools. The facility is designed for Split Hopkinson Bar Compression high strain rate testing. The system can be equip with high temperature heating system and cooling system. Advance Instrument Inc's apparatus of SHB is the direct determination of dependence of the deformation stress –strain curves and the strain rate –strain curves.

The system includes a gas gun & bar system for dynamic loading unit, which makes operation safe and easy.

Advance Instrument Inc's have works closely with Ph. D. Yuh Shiou Tai, leader of the Structure Engineering Lab Department of Civil Engineering, ROC Military Academy.

The gas gun pressure and striker bar velocity relation can be theoretically obtained by equating stored energy of gas to the kinetic energy of striker bar as the gas expands to fill the barrel.
The actual gas gun pressure vs. striker bar velocity was calibrated.
The duration of the stress pulse going through the specimen in a Split Hopkinson Bar system is dependent on the length of the striker bar and thus is fixed for a test machine.

Although there are various setups and techniques currently in use for the Split-Hopkinson pressure bar, the underlying principles for the test and measurement are the same.

A split Hopkinson pressure bar (SHPB) is a test apparatus used to obtain the material properties at 10^2 to 10^5 s-1 high strain rates.

The specimen[1] is placed between the ends of two straight bars, called the incident bar[2] and the transmitted bar[3].

At the end of the incident bar, a stress wave initial pulse[4] is created which propagates through the bar toward the specimen.

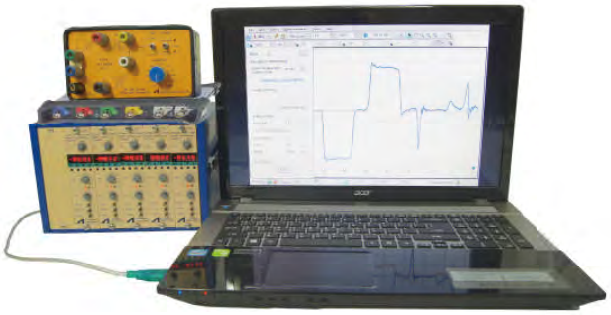
This wave is eferred pulse[5] to as the incident wave, and upon reaching the specimen, splits into two smaller waves.

One of which, the transmitted wave[6] , travels through the specimen and into the transmitted bar, causing plastic deformation in the specimen.

The other wave, called the reflected wave, is reflected away from the specimen and travels back down the incident bar.

Strains caused by the waves are measured using strain gauges[7&8] on the bars.

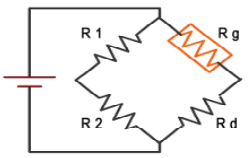
Then the stress and strain can be calculated from the amplitudes of the incident, transmitted, and reflected waves based on the assumption that the deformation in the specimen is uniform.



Measurement Devices

For bar type system, strain gauges attached to the bars are used for strain measurement. The displacement of bar / specimen interfaces can be obtained by the signals measured by the strain gauges based on an analysis of the proagation of the elastic waves in the bars.

SHB-SS SHB measurement-control program is used for data logging,post processing and analyze.



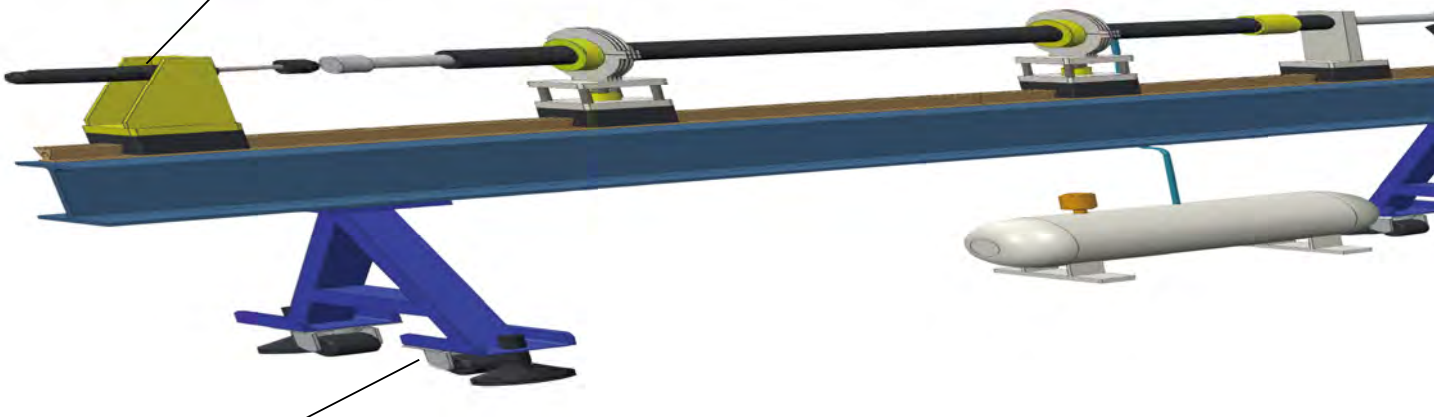
[7&8]

-Strain Measurement-

At the bar strain gauges are bonded on and electrically connected in a Wheatstone bridge.

Momentum trap system

The momentum trap device is consisting of a momentum trap bar with damper.

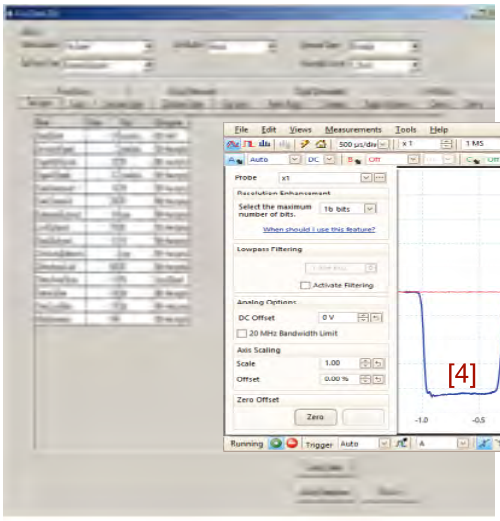


Separately Beam assembly and legs for mounting Vibration isolator mounts with leveling screws

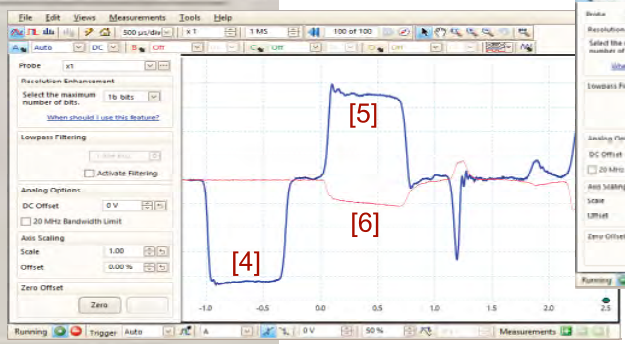
Striker bar accelerator assembly

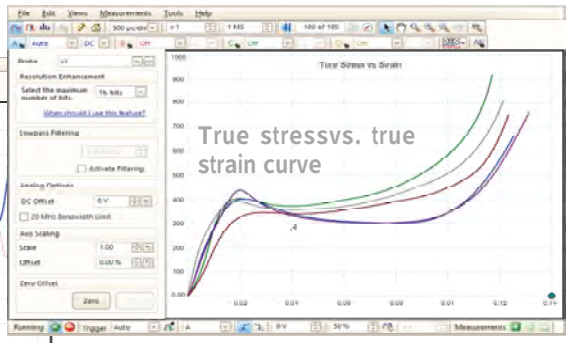
Clamping fixtures on test bar

SHPB SHTB Test Apparatus

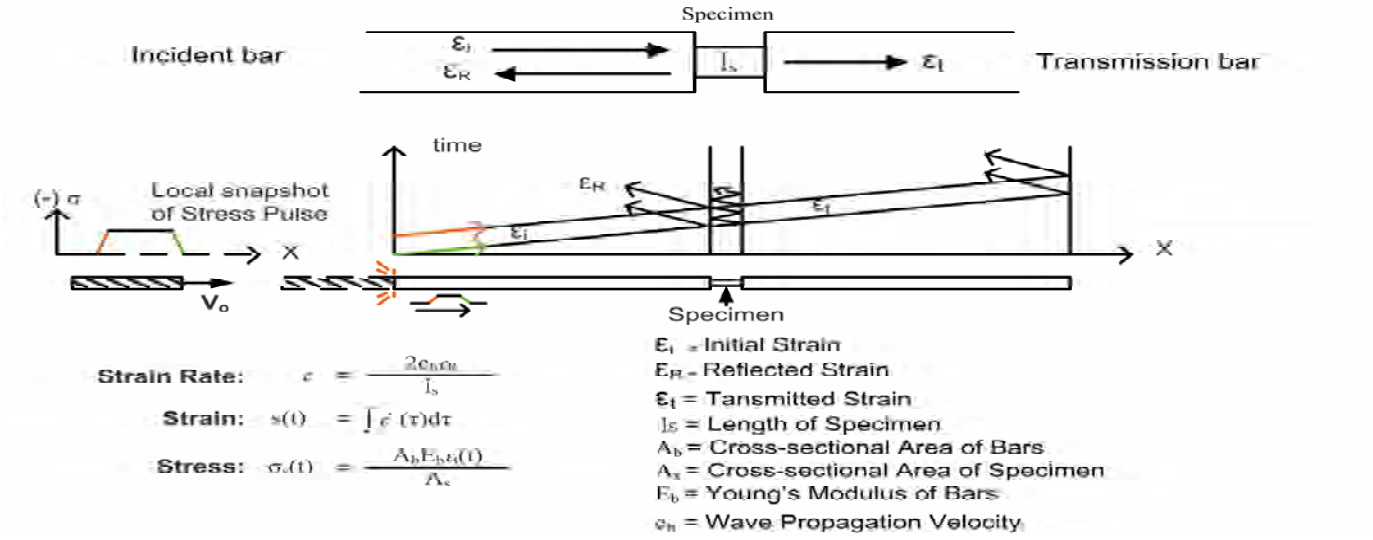


Typical
pulse signal recorded





A constant nominal strain rate throughout the test is essential to the quality of data.
The strain rate must be calculated during the test to insure that a constant rate is achieved

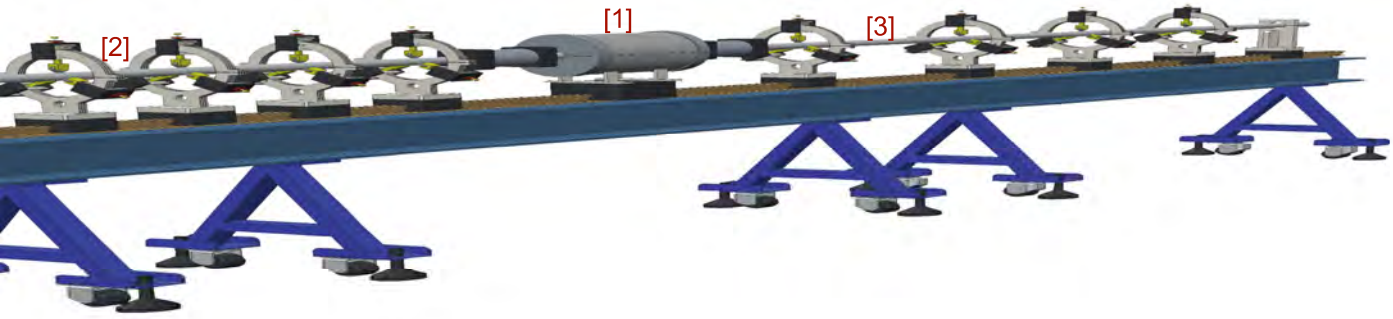


Strain Rate: $\dot{\varepsilon} = \frac{2c_b\varepsilon_R}{l_s}$

Strain: $s(t) = \int \dot{\varepsilon}(\tau)d\tau$

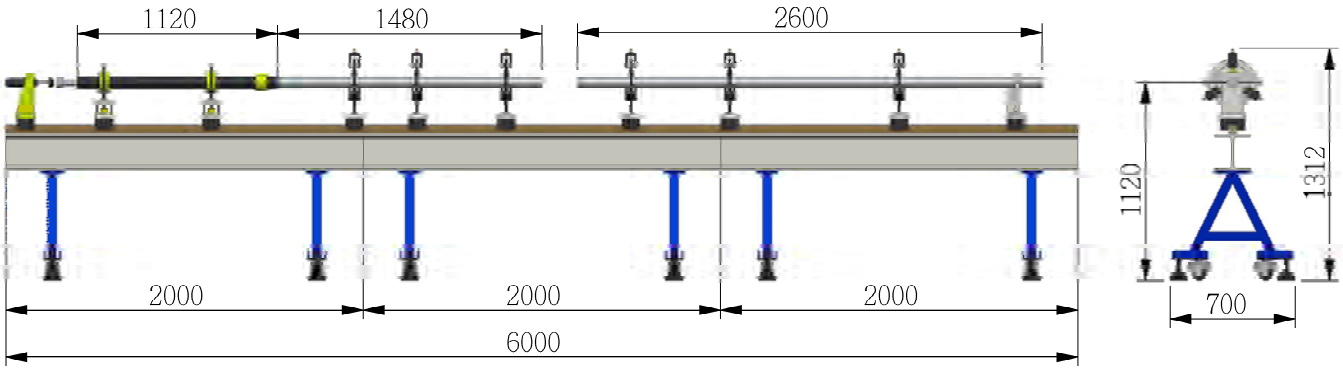
Stress: $\sigma_s(t) = \frac{A_b E_b \varepsilon_t(t)}{A_s}$

ε_i = Initial Strain
ε_R = Reflected Strain
ε_t = Tansmitted Strain
l_s = Length of Specimen
A_b = Cross-sectional Area of Bars
A_s = Cross-sectional Area of Specimen
E_b = Young's Modulus of Bars
c_b = Wave Propagation Velocity



Strike Velocity measurement system& Trigger system
Two Laser beam and phototransistor pairs are used to measure the velocity of the striker bar.
A set pre-trigger value also acquires data before the trigger event so as not to miss out the initial part of the pulse during the process of triggering.

Bar mountings with low-friction
- Precision screw-jack mount system
- Low-friction, axial direction,free movement
- Adjustable vertical and horizontal direction
- Perpendicular to the bar axis.



The split-Hopkinson pressure bar setup facility developed at Advance Instrument Inc. Those set-up can be used to test material in strain rate range of 10^2 s-1 to 10^5 s-1 . Those system have contributed immensely in material property characterization under dynamic loading condition and its application in safety related research.

The system can be delivered including the pieces of equipment; installation,training and technical consultation as complete turnkey bases.

Apparatus Type : Compression, Tension or Torsion

- ●Dynamic loading units
  - ・Pressurized Striker Bar Launcher
  - ・Bar System: Dim & Length & Material flexibility
  - ・Striker, Incident,Transmitter and Stop Bar
  - ・Momentum Trap
- ●SHB-BC Split Hopkinson Bar controller units
  - ・Strike Velocity Measurement System
- ●Dynamic Strain Acquisition units (2 ~ 8 Channels)
  - ・Strain Gage Amplifier , Bandwidth 125kHz~2M
  - ・Oscilloscope with Computer
- ●SHB-SS SHB measurement-control program
- ●Strain gages (mounting kit)
  - ・Strain gage and installation tools
- ●Training, Installation and Consultant
- ●Optional : Dynamic triaxial compression tests kit
- ●Optional : High Temperature tests kit

- ●Comprehensive training and consultant as below:
  - ・System installation & Operation training
  - ・Strain gauge mounting
  - ・Stain gage workshop Training Programs
  - ・Strain gauge measurement system & calibration
  - ・Data acquisition, Signal processing & calibration
  - ・Bar alignment and calibration
  - ・Design of experiments
  - ・Specimen preparation
  - ・Experimental procedure
  - ・Stand specimen calibration system
  - ・Analyzing the results

- ●SHB-SS SHB measurement-control program
  - ・Sets parameters, test condition, result… etc.
  - ・Reservoir pressure, striker velocity
  - ・Data acquisition Control program
  - ・Post processing and Analyze
  - ・Zoom, save and print graphs,
  - ・Test result, strain, strain rate, load, stress, true stress, elongation, true stress-strain,...etc.

The bar accelerator assembly can be used with compressed air system (7-10 bars) or by N2 gas cylinder (140 bar). The appropriate change over mechanism / hardware between the sources needs can be provided by Advance Instrument.

All Bar Systems can be compatible with existing power supply conditions of input voltage 220-230 V AC, single phase, and frequency-50/60 Hz. All power can be suitable to both the Advance Instrument equipment and user power supply source.

Advance Instrument, Inc. reserves the right, under its Continuous Improvement Policy, to change construction or design details and furnish product when so altered without reference to illustrations or specifications used herein.

Thank you for your interest to our products.

Advance Instrument Inc. www.advanceinstrument.com
Tel: 886-2-8695-1100 • Fax: 886-2-2693-1460 service@advanceinstrument.com

Split Hopkinson Pressure Bar Tester
Basic Requirements

DATE: _____

Providing as much information will lead to a more accurate costing and time saving.
Please include measurement units wherein applicable.
Use a separate new form should there be any second requirements of different parameters.

Name: _____ Phone: _____

Company Name: _____ Fax: _____

Address: _____

_____ City: _____ Zip Code: _____

Country or Province: _____ Email: _____

PRICING REQUESTED IS: ☐ ESTIMATED (FOR BUDGET PREPARATION) ☐ FIRM (FOR IMMEDIATE ORDER PLACEMENT USAGE)

TEST SPECIMEN SPECIFICATIONS

Material Code: _____ ; _____ ; _____

Material Description: _____

Material physical properties in the still tensile / compression test.

Yield Strength _____ Ultimate Tensile Strength _____

Compressive Strength _____ Poisson's Ratio _____

Young's Modulus _____

Specific Weight Hardness

Specimen Width ☐ To be proposed by vendor
_____ to _____

Specimen Thickness ☐ To be proposed by vendor
_____ to _____

Other Specifications _____

_____

ABOUT THE TEST

Test strain rate: 10^2 to 10^5 (sec^{-1}) _____ 10 ——— to _____ 10 ——— ☐ Compression ☐ Tension ☐ Torsion

Test Temperature Range _____ ; _____ ; _____

Bar Material Code and Description: ☐ To be proposed by vendor or fill-in below information.

Bar Material Code: _____

Striker Bar (mm) Diameter _____ Length _____

Incident Bar (mm) Diameter _____ Length _____

Transmitter Bar (mm) Diameter _____ Length _____

Other Parameters: _____

_____

ELECTRONIC INSTRUMENT

☐ To be proposed by vendor or fill-in below information.

Datum Rating: _____

Output Form: _____

Address: *3F, No. 6, Alley 11, Lane 351 Fude 1st Road, Hsi-chih District, New Taipei City, 22149 Taiwan*