NATO OTAN

NATO STANDARDIZATION AGENCY
AGENCE OTAN DE NORMALISATION

NSA

15 July 2004 NSA/0733-PCS/4507

See CNAD AC/326 STANAG distribution

STANAG 4507 PCS (EDITION 1) – EXPLOSIVES, PHYSICAL/MECHANICAL PROPERTIES STRESS RELAXATION TEST IN TENSION

References: AC/310-D/200, dated 16 January 2002

1. The enclosed NATO Standardization Agreement, which has been ratified by nations as reflected in the **NATO Standardization Document Database (NSDD)**, is promulgated herewith.

2. The reference listed above is to be destroyed in accordance with local document destruction procedures.

3. AAP-4 should be amended to reflect the latest status of the STANAG.

ACTION BY NATIONSL STAFFS

4. National staffs are requested to examine **their ratification status of the STANAG** and, if they have not already done so, advise the Defence Investment Division through their national delegation as appropriate of their intention regarding its ratification and implementation.

J. MAJ
Brigadier General, POL(A)
Director, NSA

Enclosure:
STANAG 4507 (Edition 1)

North Atlantic Treaty Organisation – Organisation de Traité de l'"Atlantique Nord
B-1110 Brussels Belgique
E-mail: nsa@hq.nato.int – Tel 32.2.707.3942 – Fax 32.2.707.4103

**NORTH ATLANTIC TREATY ORGANIZATION
(NATO)**

NATO STANDARDIZATION AGENCY
(NSA)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: EXPLOSIVES, PHYSICAL/MECHANICAL PROPERTIES STRESS RELAXATION TEST IN TENSION

Promulgated on 15 July 2004

J. MAJ
Brigadier General, POL(A)
Director, NSA

RECORD OF AMENDMENTS

No.	Reference/date of Amendment	Date Entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Director NATO Standardization Agency under the authority vested in him by the NATO Standardization Organisation Charter.

2. No departure may be made from the agreement without informing the tasking authority in the form of a reservation. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

4. Ratification, implementation and reservation details are available on request or through the NSA websites (internet http://nsa.nato.int; NATO Secure WAN http://nsa.hq.nato.int).

FEEDBACK

5. Any comments concerning this publication should be directed to NATO/NSA – Bvd Leopold III - 1110 Brussels - BE.

NAVY/ARMY/AIR

NATO STANDARDISATION AGREEMENT (STANAG)

EXPLOSIVES, PHYSICAL/MECHANICAL PROPERTIES STRESS RELAXATION TEST IN TENSION

Annexes:

A. Test Procedure
B. Data Exchange Format

Related document: None

AIM

1. The aim of this agreement is to standardise the stress relaxation test in tension for explosive materials.

AGREEMENT

2. The participating nations agree to use the test procedures described in Annex A and the data exchange format described in Annex B for assessing the mechanical behaviour when requested by the procuring nation.

GENERAL

3. The test described in Annex A and the data exchange format described in Annex B were developed to give every country the means to determine stress relaxation in tension of explosive materials, and to know how the results were obtained.

IMPLEMENTATION OF THE AGREEMENT

4. This STANAG is considered implemented by a nation when that nation has issued the necessary instructions putting the contents of this agreement into effect.

TEST PROCEDURE

1. Scope

This standard describes the determination of mechanical properties of explosive materials under constant tensile strain loading. The parameter obtained by the test is the tensile modulus for relaxation times lasting seconds or longer (minutes, hours). These tests are commonly conducted on rocket propellants and cast polymer bonded explosives.

The standard units for measurement are SI units. Temperature may be expressed in degrees Celsius where appropriate.

2. Definitions

The following definitions are given for measuring and reporting specimen response. Illustrations in Figures 1 and 2 are provided as a reference.

2.1 Elongation (ΔL). The change in length of the gauge part of the specimen, expressed in units of length.

2.2 Strain (ε). The ratio of elongation to the original gauge length of the specimen. Strain is dimensionless and commonly expressed as a percentage.

2.3 Stress (nominal) (σ). The force per unit area of the original specimen cross section. Stress is expressed as force per unit area.

2.4 Stress (corrected) (σ^c). The nominal stress multiplied by one plus the strain, i.e. $\sigma^c = \sigma\ (1 + \varepsilon)$. This correction is used to compensate for the reduced cross-sectional area as the specimen is strained. This correction assumes that there is no volume change. (Also known as Cauchy stress or true stress)

2.5 Relaxation Modulus (E_t). The ratio of stress to the applied strain, expressed as force per unit area per (dimensionless) amount of strain.

2.6 Elongation-Time diagram. A diagram representing the history of the applied elongation. The diagram will show a ramp-up part for applying the desired elongation, and a constant part for the remainder of the test duration. The diagram (Fig. 1) may serve as a verification that elongation is applied as intended. The unshifted time origin is at the beginning of sample deformation.

2.7 Force-Time diagram. A diagram representing the history of force response to the applied elongation loading of the specimen. The diagram may serve to provide a direct record of the response of the specimen.

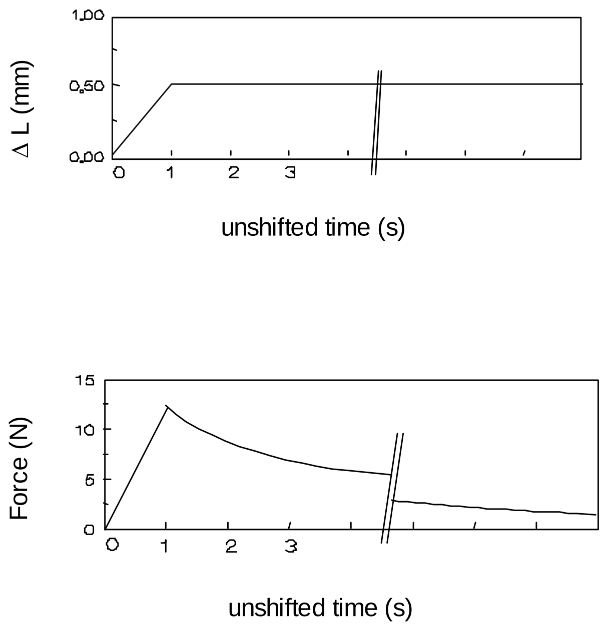


Figure 1. Elongation-Time and Force-Time diagrams showing typical histories of stress relaxation test.

2.8 Relaxation Modulus-Time diagram. A diagram representing relaxation modulus versus time (Fig. 2). The relaxation modulus is shown from a time sufficiently larger (e.g. 5-10 times) than the transient period of application of elongation.

2.9 Shifted Time (t'). Time shifted by subtracting a fraction of the ramp-up time from the unshifted time in order to account for effects of the transient period on the response of the specimen (e.g. shifted time origin is halfway ramp-up time). If such a shift is performed it should be reported.

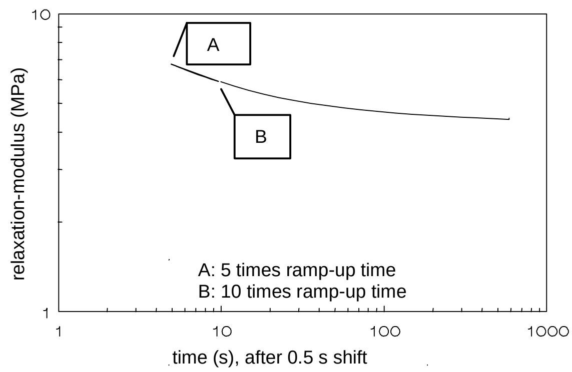
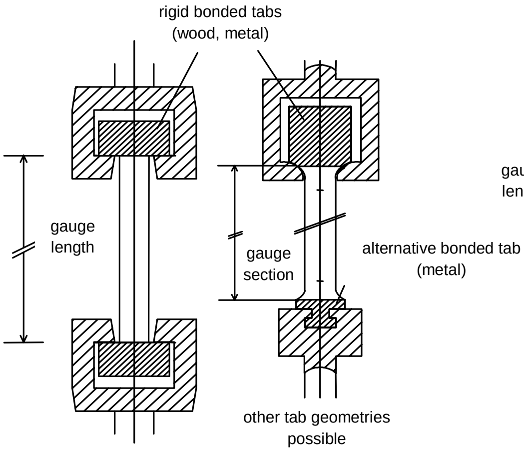


Figure 2. Relaxation-Time diagram with log-log scales.

2.10 Machine Compliance. The difference between the total displacement measured and the actual elongation of the specimen per unit of load that results from the application of load to the test specimen. If the machine distortion is a linear function of load, machine compliance should be expressed as displacement per unit force. If the machine compliance is not constant, a more complex representation must be given. The inverse of machine compliance is machine stiffness.

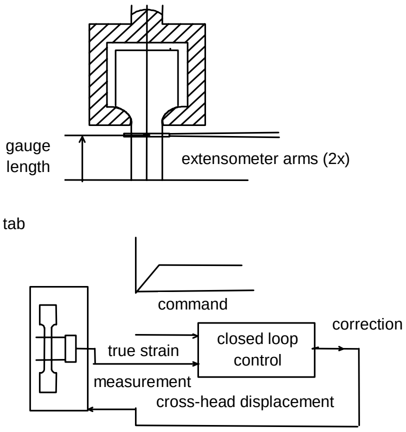
3. Test Apparatus.

3.1 Testing Machine. A testing machine with sufficient stiffness, positioning accuracy, and force measurement capabilities is required for testing tabbed specimens. Untabbed specimens can be used if the machine is equipped with strain control capabilities. The machine shall be able to generate elongation as a ramp function up to the to-be-applied elongation in a defined application time, and subsequently to keep the elongation constant within 2% during the testing time. Examples of specimen arrangements are given in Figures 3 and 4 for specimen types as mentioned. Positioning accuracy should be within .05 mm and preferably better if possible.



3(a) 3(b)

Figure 3a and 3b. Typical test arrangements for tabbed specimens.



4

Figure 4. Typical test arrangement using strain control (required for untabbed specimen).

Note: Many shapes outside gauge section are possible. Minimum gauge length is 50 mm for samples without direct strain control.

3.2 Displacement Measurement. Measurements should indicate displacement within ± 2 percent of applied elongation.

3.3 Load Measurement. The load measurement should reflect the total load carried by the specimen. Measurements should indicate load within ± 5 percent of the load at the end of the test. At least ten points per decade of time after the maximum load are required. If these conditions cannot be met it should be reported.

3.4 Specimen Grips. The centreline of the specimen and the loading axis of the test machine must coincide during measurement, as indicated in Figures 3 and 4.

3.5 Calibration. Load cells (and displacement gauges, if used) shall be calibrated against a traceable standard at least once a year. The calibration shall be carried out on the most sensitive scale and on the test scale to be used. Verification shall be conducted at the test temperature before the specimens are tested and shall be carried out and recorded as frequently as necessary to assure accurate data, but not less than once each day. Verification at the test temperature may be omitted if insensitivity to test temperature variation has been demonstrated within the last 120 days.

4. Test Specimens

4.1 Specimen Production and Storage. Specimens should be of dimensions as accurate as possible to nominal because of the sensitive nature of the test. Therefore milling is recommended as a production method (sawing of bars is acceptable). For preparation of bulk propellant and for milling conditions reference is made to paragraph 7. CAUTION: Care must be taken that the specimen deformation during production and handling is kept to an absolute minimum.

Depending on type of testing machine tabbed or untabbed specimens may be used. Geometries of these specimens are presented in Figures 5a, 5b and 6. A tabbed specimen is a specimen provided with rigid tabs (e.g. wood or metal). This type of specimen is required to exclude end-effects if no strain control is performed. Specimen 5a (tabbed bar 100x10x10 mm) is the standard specimen. Care should be taken that tab/propellant interfaces are perpendicular to the longitudinal axis so that the specimen can be symmetrically configured with the grips (v. 5.3).

Specimens shall be packed flat on plane surfaces to prevent distortion and damage. The samples provided must be representative of the manufactured material and stored in a similar manner. Exposure to atmospheric conditions (humidity and temperature) should be minimised.

Preferably, specimen preparation shall be carried out in a temperature and humidity-controlled environment. The specimens should be closely wrapped or similarly protected to prevent moisture contamination. Inclusion of a humidity indicator is recommended.

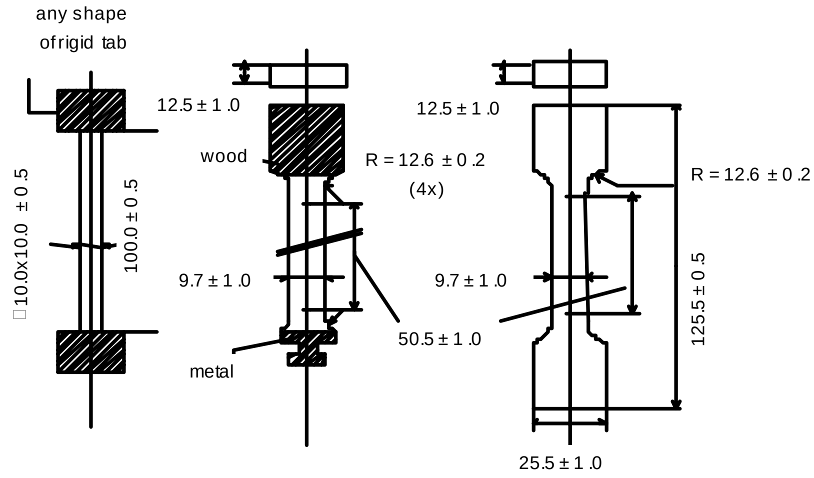


Figure 5(a) Dimensions of preferred tabbed specimen
Figure 5(b) Dimensions of alternative tabbed specimen
Figure 6 Dimensions of untabbed specimen (direct strain control required)
Adhesive for tab bonding: a two-part slow curing (20h, 20°C) epoxy (polyamide) is recommended.

5. Test method.

5.1 Measurement of Specimen Dimensions. Specimen thickness, width and length (as necessary) shall be measured prior to conditioning or testing, using an instrument or technique that permits accuracy to within 1% of measured dimension.

5.2 Specimen Conditioning. Prior to testing the specimens shall be conditioned at the test temperature for sufficient time to assure a uniform temperature distribution throughout the specimen within ± 1 °C of the desired temperature. The time required to achieve a uniform temperature will vary with factors such as material type, stacking of specimens in the conditioning chamber, and environment; however, one hour is usually satisfactory for most conditions. The temperature in the conditioning chamber shall be measured near the specimen.

It is a recommended procedure to monitor the temperature of the test specimen by embedding a thermocouple in a dummy specimen with thermal properties and characteristic dimensions similar to the test specimens. The monitored specimen should be placed among the test specimens throughout the conditioning and testing period. No specimen should be tested when the monitored specimen temperature and the conditioning box temperature deviate from the specified test temperature by more than 1 °C. This is more critical at low temperatures.

5.3 Test Procedure. Care will be taken to ensure uniform testing. The loading shall be applied symmetrically through the centre of the specimen. At least three tests are required, five are preferred. If large deviations from average values result, additional tests should be performed in order to determine the nature of the scatter.

Force and elongation data, calculated relaxation modulus, specimen dimensions and test conditions should be recorded and kept. All information required to complete the NATO Data Exchange Format as shown in Annex B should also be recorded. The complete specimen lot number, as found on the material description sheet, should be kept as the primary identifier of the specimen tested. Any test identification system should be directly linked to the lot number.

6. Data Processing.

6.1 Calculations. Strain and Stress shall be determined by Definitions 2.2, 2.3 and 2.4. All other calculations will be in accordance with the definitions listed in Section 2 or be explained in the report containing the test results (See paragraph 8 for calculation).

6.2 Report. The report of test results shall be given on the NATO AOP-7 Data Exchange Format, "Stress Relaxation Test" (See Annex B), including the source, formulation (if possible), identification numbers, and history; statement of how the specimens were prepared, and the testing conditions used; the total number of specimens tested per test condition; Elongation and Force characterisation parameters (illustrated), Relaxation Modulus (Numerical data and/or log-log graph).

7. Preparation of Bulk Propellant.

Bulk quantities of propellant from motor sections, large blocks, or cartons may need to be reduced to a size suitable for laboratory use by one of the following methods. To avoid binder-rich, diffusion affected, or damaged surfaces, cutting shall be conducted in such a manner that the skin shall be removed. The methods for reducing the size of bulk samples include sawing, machining, slicing, guillotining, and/or wire cutting. A minimum depth of 12.5 mm is recommended to be removed from the block or bulk sample. Cutting should be done at room temperature with relative humidity below 50% . Machining rates will depend on geometry and modulus.

Storage conditions of specimens shall be carefully maintained. Inadequate control of the storage conditions can lead to wide variations in test results. In particular, many explosive materials are sensitive to variation in temperature and humidity.

8. Calculations (for paragraph 6.1)

Typical curves of elongation versus time and force versus time are presented in Figure 7.

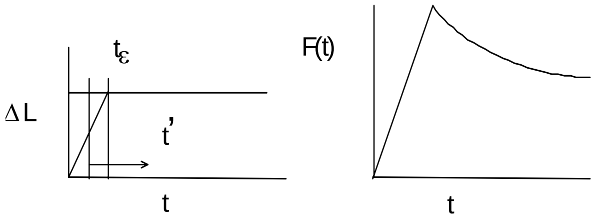


Fig. 7. Elongation versus time (with shifted time indicated) and force versus time

Stress, strain, moduli and shifted time shall be calculated as follows:

$\sigma(t) = F(t)/A_0$

$\sigma^c(t) = \sigma(t) * (1+\varepsilon)$

$\varepsilon_{applied} = \Delta L_{applied} / L_0$

$E(t) = \sigma(t) / \varepsilon_{applied}$ or: $E^c(t) = \sigma^c(t) / \varepsilon_{applied}$

$E_t = E(t)$

$t' = t - \alpha * t_\varepsilon$, with $0 < \alpha < 1$ (e.g. $t' = t - 1/2\ t_\varepsilon$)

If shifted data are derived then E(t') or $E^c(t')$ should be calculated and presented both as a table E vs t' and in a log-log graph.

A typical curve of modulus versus time is shown in Figure 8. The modulus is shown after a certain time only, as stated in paragraph 2.8.

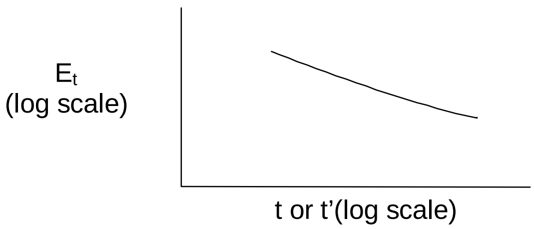


Fig. 8. Modulus versus time (log-log scales)

DATA EXCHANGE FORMAT

Report Reference Number :

Stress Relaxation Test

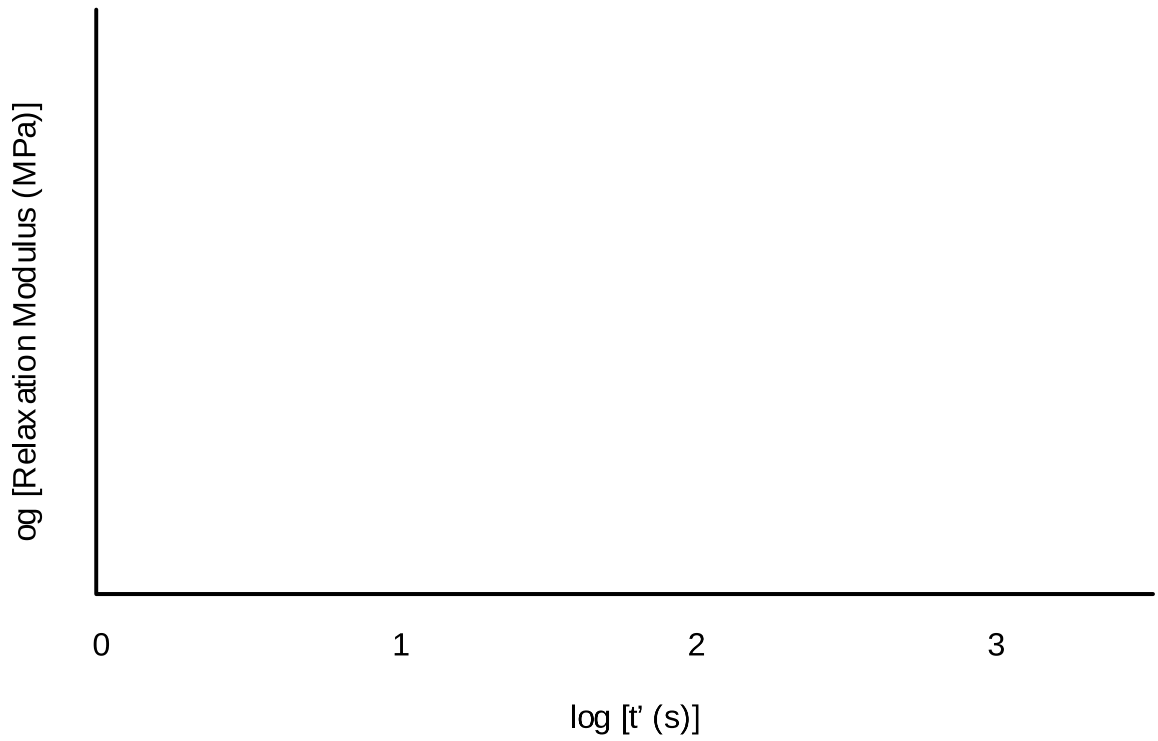
Page ___ of ___ Page(s)

TEST SITE INFORMATION	**TEST CONDITIONS**
Laboratory : Date : Test Procedure : NATO Test Procedure Number : Date Tested:	Temperature (°C) : Relative Humidity (%) : Strain Rate (s^{-1}) : Strain (%) : Machine Type: Active strain control: **YES ☐** **NO ☐** Grip Type :

SPECIMEN INFORMATION

Dimensions (mm) :
    Length (gauge length) :
    Width :
    Thickness (diameter) :
    Cross sectional area (mm²) :
Form :
Preparation Method:
Manufacturing Method :
Source :
Lot or ID number :
Conditioning Period :
	Name :
	Composition :
	
	Component Percent
	______ ______
	______ ______
	______ ______
	______ ______
	______ ______
	______ ______
	______ ______

TYPICAL RESULTS



DATA EXCHANGE FORMAT

Report Reference Number : *(Unique Reference Number)*

Stress Relaxation Test

(Instruction Sheet)

Page ___ of ___ Page(s)

TEST SITE INFORMATION	**TEST CONDITIONS**
Laboratory : *(Name of Laboratory)* Date : *(Date that form was completed)* Test Procedure : *(Name of Test Procedure Used)* NATO Test Procedure Number : *(Test Procedure Number)* Date Tested: *(Date of Test)*	Temperature (°C) : *(Specimen Temperature)* Relative Humidity (%) : *(Room Relative Humidity)* Strain Rate (s^{-1}) : *(During Loading)* Strain (%) : *(Constant Strain Rate)* Machine Type: *(Name and Model Number of Machine)* Active strain control : **YES** ☐ **NO** ☐ Grip Type : *(Name and Model Number of Grip)*

SPECIMEN INFORMATION

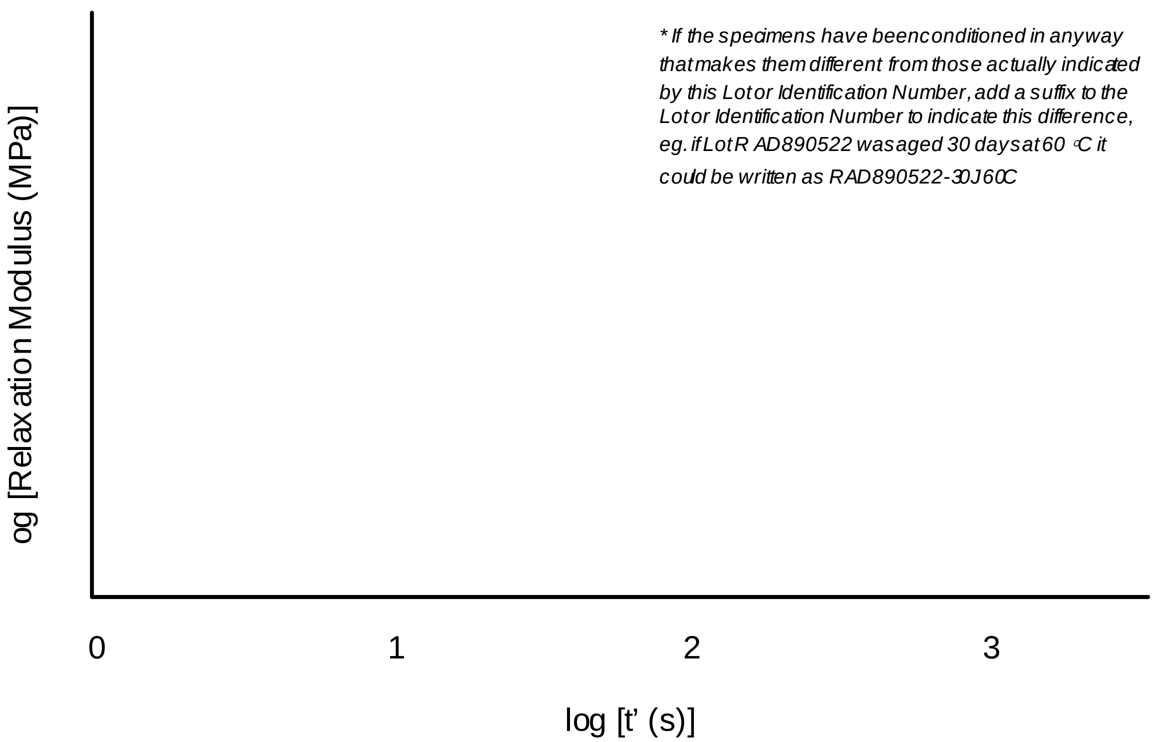
Dimensions (mm) :
- Length (gauge length) : *(Mean Specimen Length)*
- Width : *(Mean Specimen Width)*
- Thickness (diameter) : *(Mean Specimen Diam.)*
- Cross sectional area (mm²) : *(Nett Area)*

Form : *(Specimen Geometry Descriptor)*
Preparation Method: *(Specimen Preparation Method)*
Manufacturing Method: *(Specimen Processing Technique)*
Source : *(Name of Manufacturer)*
Lot or ID number : *(Same as on PDS)**
Conditioning Period : *(Period Specimen was Conditioned)*

Name :
Composition :

Component	Percent
______	______
______	______
______	______
______	______
______	______
______	______
______	______

TYPICAL RESULTS



** If the specimens have been conditioned in any way that makes them different from those actually indicated by this Lot or Identification Number, add a suffix to the Lot or Identification Number to indicate this difference, eg. if Lot R AD890522 was aged 30 days at 60 °C it could be written as RAD890522-30J60C*

DATA EXCHANGE FORMAT

Report Reference Number :

Stress Relaxation Test
(Example Sheet)

Page 1 of 2 Page(s)

TEST SITE INFORMATION	**TEST CONDITIONS**
Laboratory : PML – TNO Date : 23/05/91 Test Procedure : Uniaxial Tensile Stress Relaxation NATO Test Procedure Number : 102.01.003 Date Tested: 26/03/91	Temperature (°C) : - 40 Relative Humidity (%) : < 30 Strain Rate (s^{-1}) : 0.01 Strain (%) : 1.0 Machine Type: Zwick 1445 Active strain control : **YES** ☐ **NO** ☐ Grip Type : NA

SPECIMEN INFORMATION

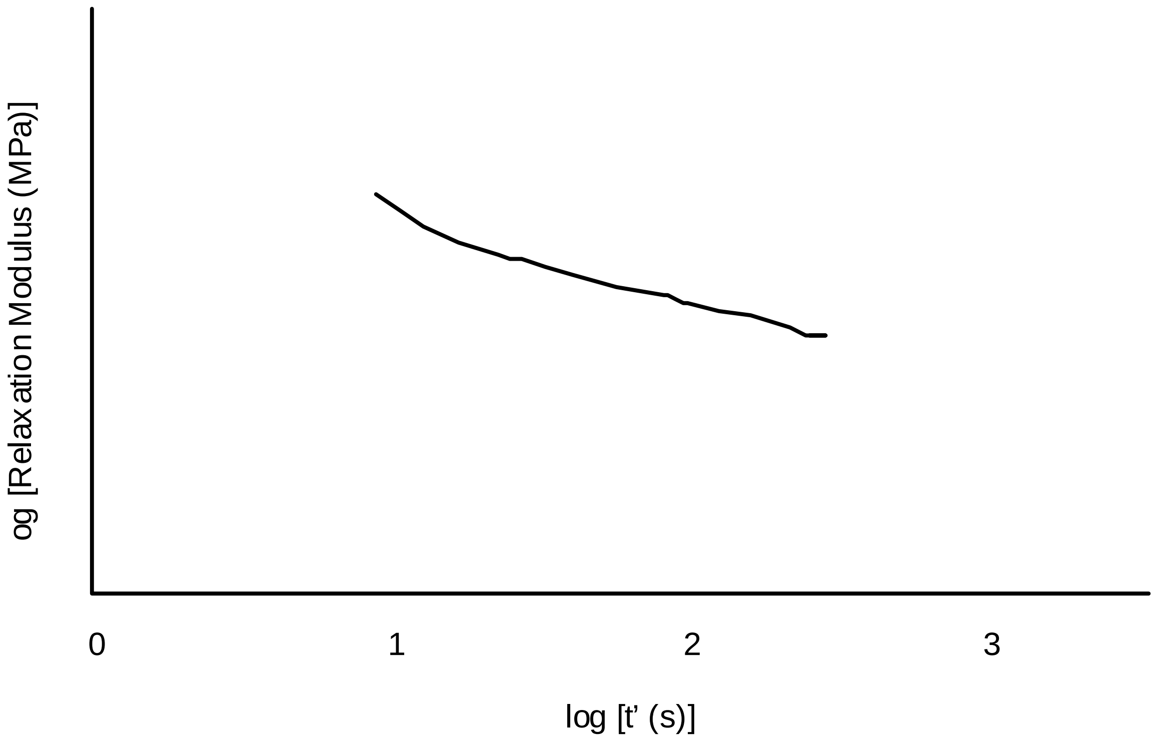
Dimensions (mm) :
- Length (gauge length) : 50.0
- Width : 8.82
- Thickness (diameter) : 12.81
- Cross sectional area (mm²) : 113.0

Form : Untabbed Dogbone
Preparation Method: Sawing from Cast Block
Manufacturing Method : Milling
Source : PML – TNO
Lot or ID number : CK-3025-38-4
Conditioning Period : 1 hr

Name : MX-B5
Composition :

Component	Percent
AN	69
Filler	12
MTPB	12
IDP	7
Total	100

TYPICAL RESULTS



DATA EXCHANGE FORMAT

Report Reference Number :

Stress Relaxation Test

Page ___ of ___ Page(s)

Test ID :

Data Disk ID : File ID : Format :

Options :

$$E_t = \frac{\sigma}{\varepsilon} \quad or \quad E_t^c = \frac{\sigma}{\varepsilon}(1+\varepsilon)$$

t' = t - ____________

Comments :

Shifted Time (s) versus Relaxation Modulus (MPa)

t' (s)	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Observation

Data Sent To :

DATA EXCHANGE FORMAT

Report Reference Number : *(Unique Reference Number)*

Stress Relaxation Test

(Instruction Sheet)

Page ___ of ___ Page(s)

Test ID : *(Test ID Number)*

Data Disk ID : *(Name of Disk)* File ID : *(Name of File)* Format : *(Format of Disk)*

Options :

$$E_t = \frac{\sigma}{\varepsilon} \quad or \quad E^c_t = \frac{\sigma}{\varepsilon}(1+\varepsilon)$$

t' = t - ____*(fill in)*_________

(Strike one of the Formulas)

Comments :

Shifted Time (s) versus Relaxation Modulus (MPa)

t' (s)	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Observation
Time shifted y Amount ndicated bove)	*Relaxation odulus of pecimen 1)*	*Relaxation odulus of pecimen 2)*	*Relaxation odulus of pecimen 3)*	*Relaxation odulus of pecimen 4)*	*Relaxation odulus of pecimen 5)*	

Data Sent To : *(Name and Address of Person Receiving This Information)*

DATA EXCHANGE FORMAT

Report Reference Number : JM001

Stress Relaxation Test
(Example Sheet)

Page 2 of 2 Page(s)

Test ID : RE – 910326-02

Data Disk ID : File ID : Format :

Options :

$E_t = \frac{\sigma}{\varepsilon}$ or ~~$E^c_t = \frac{\sigma}{\varepsilon}(1+\varepsilon)$~~

t' = t - 0.5 s

Comments :

One Specimen Only

Shifted Time (s) versus Relaxation Modulus (MPa)

t' (s)	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Observation
0	-					
1	-					
10	27.0					
20	23.0					
50	21.4					
100	19.9					
200	18.9					
500	17.0					
600	16.5					

Data Sent To : Ron Lieb,
ASRL-WT-PE
Aberdeen Proving Groud, MD 21005-5066
USA