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**Rubber, vulcanized — Determination of  
stress in tension upon heating**

*Caoutchouc vulcanisé — Détermination de la contrainte en traction  
lors du chauffage*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12493 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis*.

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## Introduction

Vulcanized rubber held under a constant stress will contract as the test temperature is raised, while a test piece held under a constant strain will develop an increased stress. These are features of the Gough-Joule effect in rubber and, unless they are taken into account at the design stage, any resulting changes in forces and dimensions can affect the performance of some products, such as rotary seals, used at high temperatures and high strains (see Reference [1] in the Bibliography).

This International Standard describes a test method for the determination of the change in tensile stress that results from an increase in test temperature.

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# Rubber, vulcanized — Determination of stress in tension upon heating

## 1 Scope

This International Standard specifies a method for measuring the stress in tension which is developed in vulcanized rubber when it is heated (thermal stress). The thermal stress is measured for various pre-strain and temperature conditions as a function of time.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 18899:2004, *Rubber — Guide to the calibration of test equipment*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

### 3.1

#### thermal stress

$\sigma_T$   
force per initial unit area which is developed in the test piece upon heating

NOTE It is expressed in N/m<sup>2</sup> or Pa.

### 3.2

#### maximum thermal stress

max.  $\sigma_T$   
peak value of the thermal stress recorded during the test

### 3.3

#### thermal stress after a specified time

$\sigma_{T,t}$   
stress induced in the test piece upon heating for a specified time  $t$

### 3.4

#### pre-strain

elongation to which the test piece is subjected at the beginning of the test

NOTE It is expressed as pre-strain =  $\frac{l_f - l_i}{l_i}$

where

$l_i$  is the initial length;

$l_f$  is the length after elongation.

### 3.5

#### **pre-stress**

force per initial unit area which results from the pre-strain

NOTE It is expressed in N/m<sup>2</sup> or Pa.

## 4 Principle

A test piece is held at a constant pre-strain in a tensile mode at standard laboratory temperature. When the pre-stress resulting from the given pre-strain has reached an apparent equilibrium value, the temperature of the test piece is increased. The thermal stress developed at the elevated temperature is measured for various pre-strain conditions as a function of time.

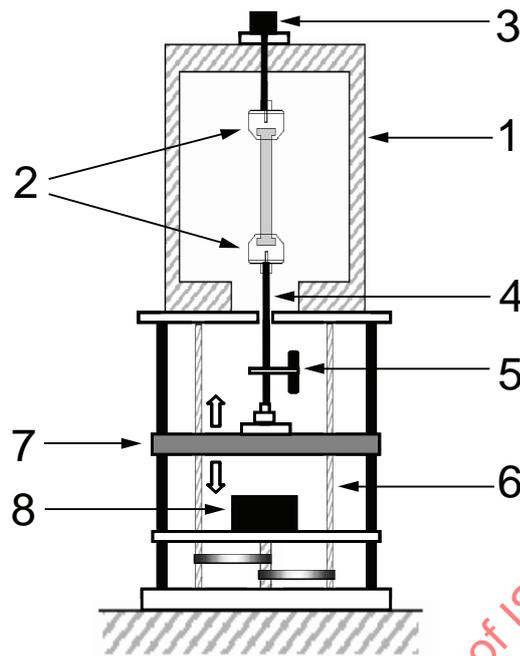
## 5 Apparatus

### 5.1 Thermal-stress testing machine

An example of a test machine for measuring the thermal stress developed in rubbery materials when heated is shown in Figure 1. Two clamps hold the test piece in a temperature-controlled chamber, with the upper clamp connected to a load cell and the bottom clamp connected to a crosshead. The crosshead is moved using a screw driven by a motor to impose a pre-strain on the test piece. The thermal stress developed when the temperature is raised is transmitted to the load cell and the output is recorded to give the variation in stress as a function of time.

The test machine shall comply with ISO 5893 with force measurement to class 1 and the machine shall be capable of setting the pre-strain to within  $\pm 0,1$  at a speed of  $(20 \pm 2,5)$  mm/min.

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**Key**

- 1 temperature-controlled chamber
- 2 clamps
- 3 load cell
- 4 rod
- 5 linear variable differential transformer
- 6 screw
- 7 crosshead
- 8 motor

Figure 1 — Example of thermal-stress testing machine

## 5.2 Temperature-controlled chamber

The temperature-controlled chamber shall be capable of raising the temperature at a rate of at least 30 °C/min and maintaining the test piece at the required temperature as specified in ISO 23529. A suitable volume for the chamber is 3 litres to 5 litres. A temperature-sensing device shall be located within the chamber near the test piece.

## 5.3 Thickness- and width-measuring devices

Instruments for measuring the thickness and width of the test piece shall be in accordance with ISO 23529.

## 6 Calibration

The test apparatus shall be calibrated in accordance with the schedule given in Annex A.

## 7 Test piece

### 7.1 Dimensions

The test piece shall be prepared by cutting from moulded flat sheet and shall have the shape and dimensions shown in Figure 2. In addition, the thickness shall be  $(2 \pm 0,2)$  mm. The test piece shall have a smooth surface and be free from irregularities.

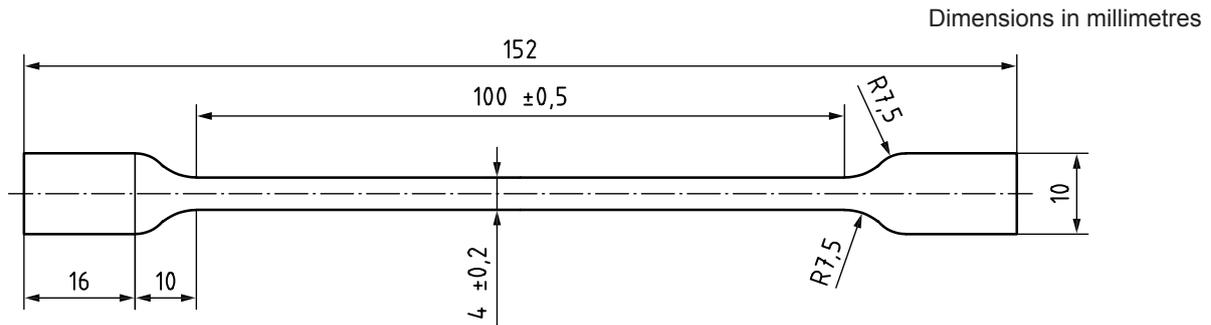


Figure 2 — Test piece for thermal-stress measurements

## 7.2 Number of test pieces

At least three test pieces shall be used for each set of test conditions.

## 7.3 Time lapse between moulding and testing

Unless otherwise specified, the following requirements shall be observed (see ISO 23529):

- For all test purposes, the minimum time between moulding and testing shall be 16 h.
- For non-product tests, the maximum time between vulcanization and testing shall be four weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time interval.
- For product tests, whenever possible, the time between vulcanization and testing shall not exceed three months. In other cases, tests shall be made within two months of the date of receipt of the product by the customer.

## 7.4 Conditioning

Test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing.

Test pieces shall be conditioned at a standard laboratory temperature for at least 3 h immediately before being measured and tested.

If the test is to be carried out at a starting temperature other than a standard laboratory temperature, the test pieces shall be conditioned at the test temperature immediately prior to testing for a period sufficient to ensure that they have reached the test temperature (see ISO 23529).

## 8 Test conditions

### 8.1 Temperature

The elevated temperatures to be used shall be selected from those specified in ISO 23529 unless otherwise necessary for technical reasons. Recommended test temperatures are 60 °C, 100 °C and 140 °C.

### 8.2 Pre-strain

A minimum of three pre-strains at each temperature shall be selected. Recommended pre-strains are 0,2, 0,4 and 0,6.

## 9 Procedure

Mount a test piece in the clamps at a standard laboratory temperature and elongate it to the required pre-strain by movement of the crosshead at a speed of  $(20 \pm 2,5)$  mm/min, as shown in Figure 3. Hold the test piece at the constant pre-strain until the pre-stress resulting from the pre-strain reaches an apparent equilibrium value. This will be after about 30 min. Then, reset the load cell to zero and increase the temperature to the required test temperature. Start recording the thermal stress immediately after the heating begins (designated as zero time). Monitor the development and decay of the thermal stress as a function of time. The minimum duration of the test shall be 30 min.

Unless otherwise specified, carry out the test to obtain results at a minimum of three temperatures, with three pre-strains at each temperature.

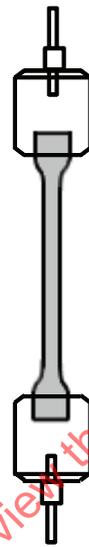


Figure 3 — Schematic diagram of a test piece with clamps at a constant pre-strain

## 10 Expression of results

Plot the thermal stress in the test piece as a function of time. From the graph, obtain the maximum thermal stress, the time to reach the maximum thermal stress, and the thermal stress at a specified time, which shall be taken as 20 min unless otherwise specified.

An example of the thermal stress of an unfilled natural rubber (NR) vulcanizate at a pre-strain of 0,4 is shown in Figure 4 as a function of time at three different temperatures.

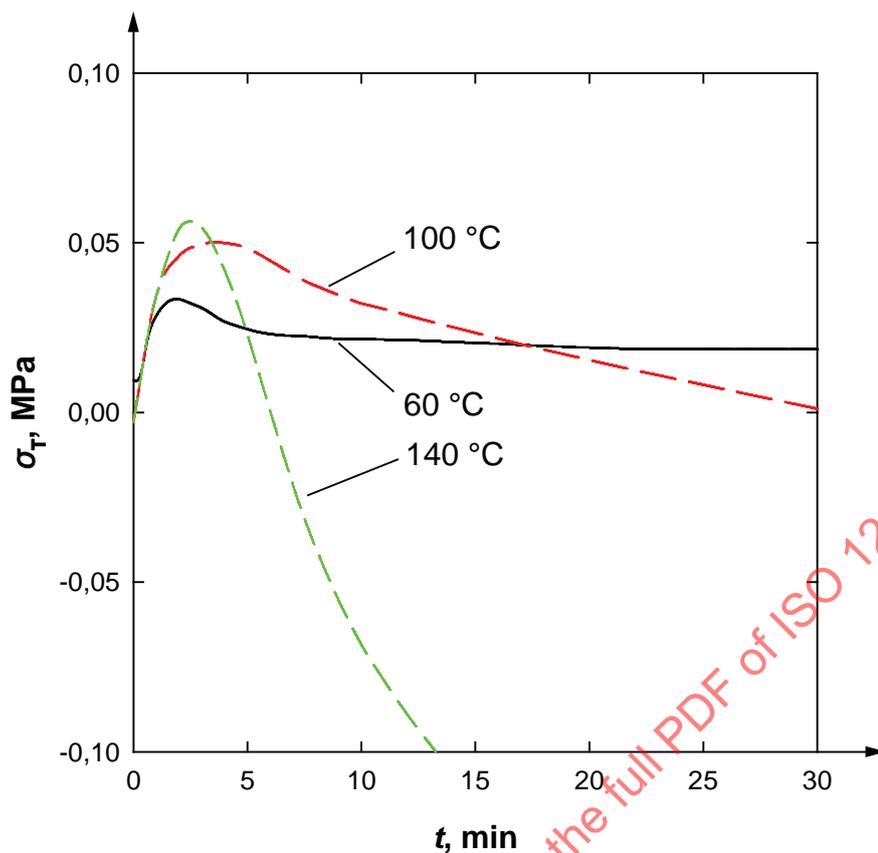
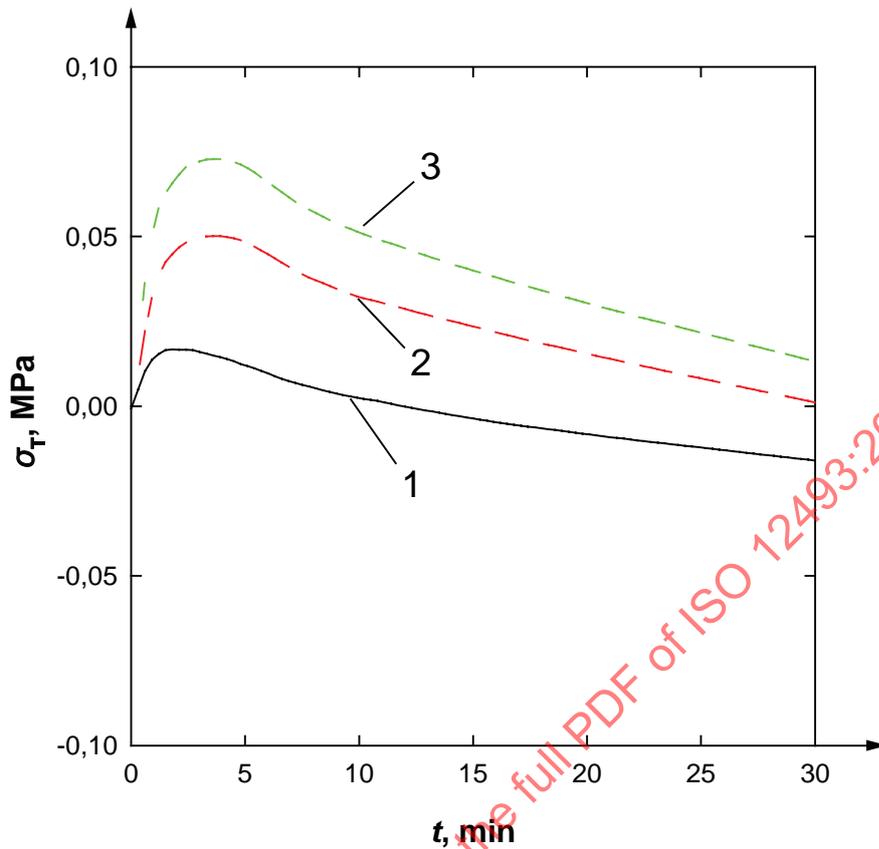


Figure 4 — Thermal stress at various temperatures of an unfilled NR vulcanizate at a pre-strain of 0,4

Another example of the thermal stress of an unfilled NR vulcanizate at a test temperature of 100 °C is shown in Figure 5 as a function of time at three different pre-strains.



#### Key

- 1 pre-strain 0,2
- 2 pre-strain 0,4
- 3 pre-strain 0,6

Figure 5 — Thermal stress at various pre-strains of an unfilled NR vulcanizate at a test temperature of 100 °C

## 11 Precision

No precision data are currently available for this method.

## 12 Test report

The test report shall include the following information:

- a) a full description of the sample and its origin;
- b) a full reference to the test method used, i.e. the number of this International Standard;
- c) test details:
  - 1) the standard laboratory temperature used,
  - 2) the time and temperature of conditioning prior to the test,
  - 3) the test temperatures used,
  - 4) the pre-strains used,

- 5) details of any procedures not specified in this International Standard;
- d) test results:
  - 1) the number of test pieces used,
  - 2) the graph(s) plotted of thermal stress against time,
  - 3) the mean values of the individual results from the graph(s) — maximum thermal stress (max.  $\sigma_T$ ), time to maximum thermal stress, and thermal stress after a specified time ( $\sigma_T, t$ );
- e) the date of the test.

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