Test&Motion
Application Module:

ME 5 – Determination of r + n value

Version 1.0 (State 20160819)

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1 Introduction

Dear customer, thank you for choosing a product of **DOLI Elektronik GmbH**. **Test&Motion** is a modern application for the operating systems Microsoft Windows XP/7/8/10©.

This manual does not deal with the **Test&Motion software** in general but with the application module Plastics Tensile Test ME 5 in particular. Hence, it is recommended to read the **Test&Motion** application manual in order to get familiar with the software. Please follow the demands and safety hints listed in the manual!

1.1 Symbols

The different symbols in this manual will allow you to find your way more easily.

Table 1: Symbols and their meanings.

Symbol	Meaning
	**Safety Instructions:** **In order to avoid interruptions in the work flow as well as damages to man and machine, follow the safety instructions at all cost.**
	**Job/work instructions:** **Instructive part of the document with precise work instructions.** **Here you are asked to do something.**
	**Information:** **General information and descriptions of working procedures, etc.**
	**Note:** **Important note for the operation, the function or for the working procedures.**
	**Tip:** **Gives tips for easy handling of the Test&Motion Software, the EDCs or the testing instrument.**

2 Application module ME 5: Determination of r + n value

2.1 Field of application

Tensile test for metallic materials Part 1

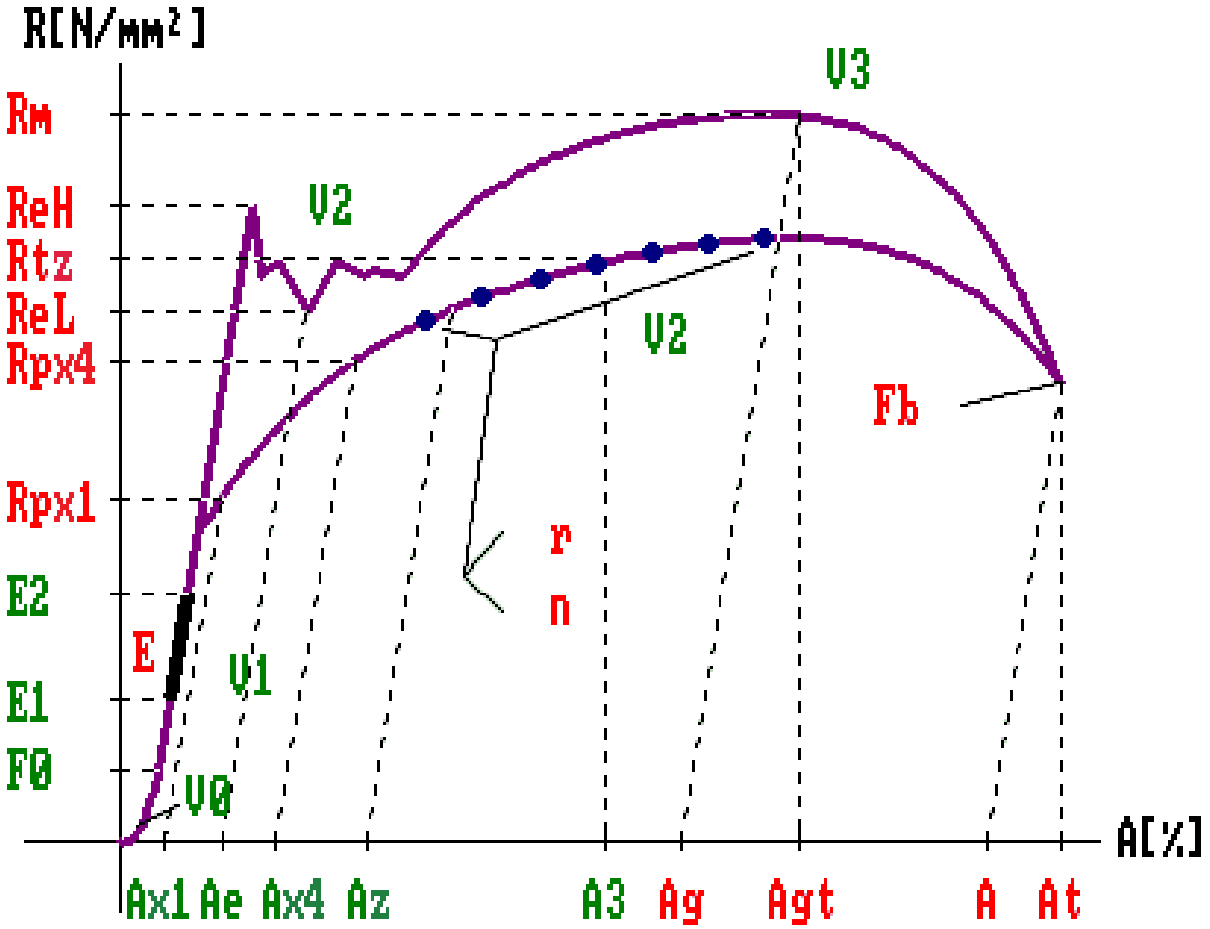
Test method at room temperature

Determination of offset yield stresses, apparent yielding points, tensile strength, breaking force including the pertinent extensions and the E module as well as reduction in area when breaking in the tensile test to DIN EN ISO 6892-1.

Test control is possible with 2 different methods.

- Method A - Elongation controlled, controlled via signal of extensometer
- Method B - Load controlled (stress controlled)

2.2 Test graphic ME 5



2.3 Input values ME 5

1. Click Menu Test → Command Settings → Input values. Here you can find expedient input values for this test regulation, already. If necessary adjust the values to your needs.

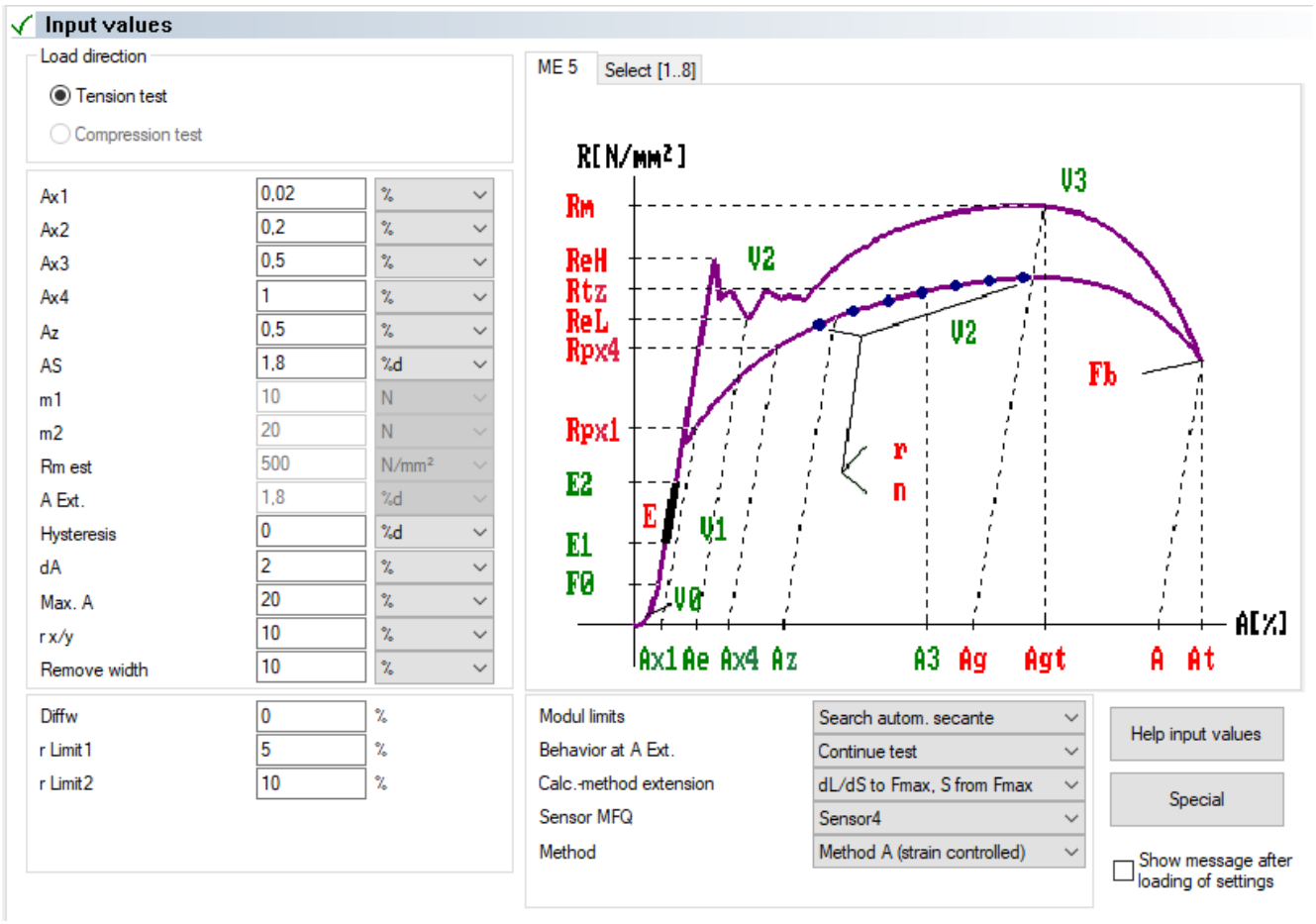


Table 2: Input values for test ME 5.

Parameter	Meaning	Dimension / Selection possibilities
Ax1	Non-proportional extension 1 (reference value)	[%]
...		
Ax4	Non-proportional extension 4 (reference value)	[%]
Az	Overall extension (reference value)	[%]
AS	Switching point of test speeds from V1 to V3	• [%d] Non-proportional extension • [%abs] Overall extension • [mm] mm absolute • [N/mm²] Stress absolute

m1	Youngs modulus limit 1	[N, kN], [N/mm²]
m2	Youngs modulus limit 2	[N, kN], [N/mm²]
Rm est	Rm estimated	[N/mm²]
A Ext.	Point for remove extensometer	Dimensions like AS
Hysteresis	Reload curve if value > 0	Dimensions like AS
d A	Difference of strain points for determination of r + n - Value	[%]
Max. A	Maximum value for strain point (<= 20%)	[%]
r x/y	A width value is required to determine the r value. This input value determines at which point this width value is determined.	[%]
Remove witdh	Remove width sensor at xx [%] total elongation	[%]
Diffw		[%]
r Limit 1	Editable limit l1	[%]
r Limit 2	Editable limit l2	[%]
Modul limits	Limits within the modulus of elasticity is calculated. (Automatic search or input values)	• Search autom. 'secant' • Input value m1, m2 • Search autom. regress. line • Aut. regress.coeff. < 0.999
Behaviour at A Ext.		• Continue test • Stop, clip off ext. • Continue test, clip off ext.
Calculation method strain		• dL/dS to Fmax, S from Fmax • dL + dS from A Ext. • dL/dS-modul to test end
Sensor MFQ	Sensor channel for width measurement	• Sensor 4 • … • Sensor 15
Test method	Methods	• A (elongation controlled) • B (stress controlled)

2.4 Hints ME 5

The input values E1 and E2 are only relevant if for selection "Module-limits" “Input values E1 and E2” was selected.

Test method A (strain controlled), favored by the standard. as test speed V1 is a value 0.00007 [1/s dL] is specified, that means 0.00007 Le/sec. When Le = 50 mm corresponds to a length change rate of 0.00007 * 50 * 60 = 0.21 [mm / min dL]. This speed is measured between the arms of the extensometer. The crosshead speed is higher in order to realize this length rate of change. We move with that speed over the entire module area up to the switch point AS. This point should be behind Ax1 to Ax4, so that the yield strength can be measured even at the speed V1. A speed change always generates a force increase that does not come from the material. This increase in force possibly could coincide with the determination of a yield point. The change of test speed should not be suddenly, better linearly increasing over a time period (10 sec).

Test method B (stress controlled), was previously in metal tensile test usual. Unlike the outdated (invalid) standard EN 10002 of the module line will be switched to position control (xhead) before leaving.

This crucial change to the previous standard has the following cause.at the first signs of plastic deformation the measured value curve deviates from the straight line bends to the right. If the machine is in force regulation (load-controlled), so speed is increased in order to continue to ensure the linear slope of the curve on the unit controls. Depending on the control parameters and the maximum speed of the machine that works more or less well. The curve and thus the test results are thus dependent on the machine and its control parameters. That can not be logically, because the test results should not be dependent on the testing machine, only on the material.
The test method B requires that the crosshead moves in the loading direction, while the stress rise is dependent on the elastic modulus are within certain limits.

Modulus	< 150 kN / mm²	2-20 MPa / s
Modulus	>= 150 kN / mm²	6-60 MPa / s

We thus begin after reaching the initial force with force control (fe. 10 MPa / s) and switch on reaching input value Rm est / 2 order to position control. The xhead speed is maintained, which has been adjusted due to the force control at the switchover Rm est / 2. Rm est / 2 is generally before the point at which the rise line is left, and the plastic deformation starts. If this is not so, so enter for Rm est a smaller value. With this process, we ensure that the required test speed is ok and no speed increase occurs simultaneously with incipient plastic deformation. Analogously to Method A is switched at reaching changeover AS on V3.

2.5 Results ME 5

1. Click Menu Test → Command Settings → Results. Here you can already find expedient results. If necessary, adjust the values to your needs.

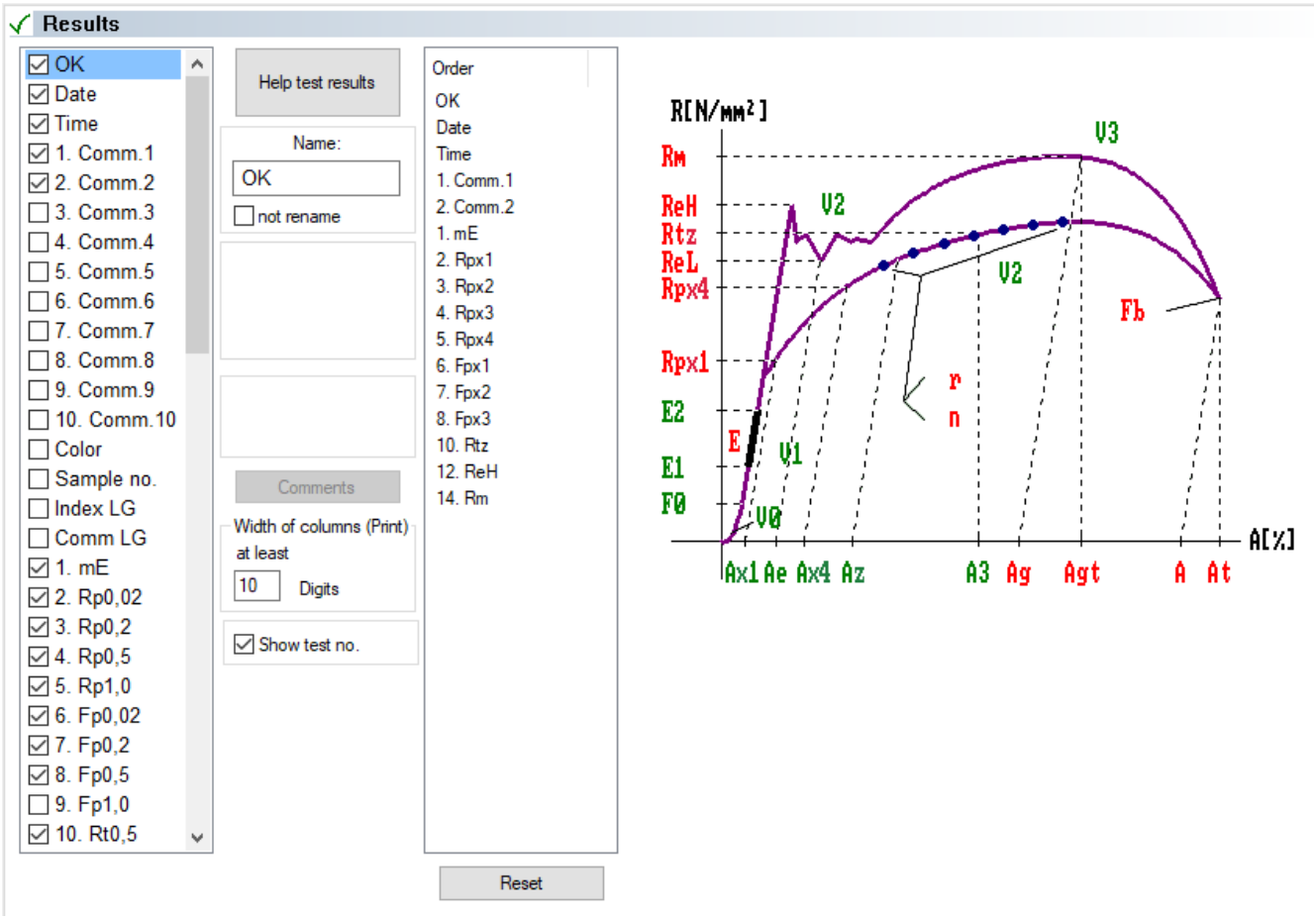


Table 3: Results for test ME 5.

Parameter	Meaning	Dimension
mE	Tensile modulus	[kN/mm²], [GPa]
Rpx1	Yield strength at non-proportional strain Ax1	[N/mm²]
…		
Rpx3	Yield strength at non-proportional strain Ax4	[N/mm²]
Fpx1	Load at non-proportional strain Ax1	[N]
…		
Fpx4	Load at non-proportional strain Ax4	[N]
Rtz	Stress at total elongation Az	[N/mm²]
Ftz	Load at total elongation Az	[N]
ReH	Upper yield strength	[N/mm²]
ReL	Lower yield strength	[N/mm²]

Rm	Tensile strength (tensile stress at maximum test load)	[N/mm²], [MPa]
Fm	Maximum test load	[N]
Fb	Breaking load	[N]
Ae	Apparent yielding point extension	[%]
Ag	Non-proportional extension at maximum force	[%]
A	Breaking extension	[%]
Agt	Overall extension at maximum force	[%]
At	Overall extension at sample break	[%]
Su	Smallest test piece section after sample break	[mm²]
Z	Reduction in area when breaking	[%]
A5	Calculated extension if Le = 50 mm	[%]
A10	Calculated extension if Le = 100 mm	[%]
L0	Initial measured Length	[mm]
S0	Sample diameter	[mm²]
a	Sample dimension	[mm]
b	Sample dimension	[mm]
h	Sample dimension	[mm]
m	Sample weight	[g]
Lu	Sample elongation (manual input)	[mm]
Le	Gauge length	[mm]
a u	Reduced sample dimension	[mm]
b u	Reduced sample dimension	[mm]
FeH	Load at upper yield strength	
FeL	Load at lower yield strength	
Rp 0,0	Yield strength at initial-proportional strain	[N/mm²]
Fp 0,0	Load at initial-proportional strain	[N]
Re / ReH	Yield strength ratio	
Rm / Rp0.2	Yield strength ratio	
r	r-value indicates the vertical anisotropy	
n (4..MaxA)	n-value indicates material work hardening under plastic deformation	
n (5..8)		
n (8..12)		
n (4..Ag)		
n (5..Ag-1)		
n (2..Ag-1)		
r (l1-l2)	r value between limits l1 and l2	

n (l1-l2)	n value between limits l1 and l2	
RPC	Value acc. GOST standard,	
n (10-20 %Ag)		
n (10-17 %Ag)		
n (5-15 %Ag)		
r (Ag)		
r (Average)		

2.6 Hints for the test ME 5

2.6.1 Pre-load F0

For the test control, the elongation and the strain will be set to zero when pre-load F0 is reached (see explanations about elongation and strain further down, also).

The measuring length then will be corrected to **L0' = L0 + dL(F0)**

whereas
L0' *corrected measuring length*
L0 *measuring length*
dL(F0) *sample deformation at F0*

2.6.2 Test rates

For the test control 4 different test rates are possible in load direction, whereby switching over V0/V1 is carried out in general at F0. The switching over points V1/V2 and V2/V3 are permanently programmed to EN ISO 6892-1 or can be entered in the dialogue window "test settings | rates", whereby these must be entered as smaller values than the permanently switching over points.

Permanently programmed criteria for the rate switching over:

V0 → V1 F0

V1 → V2 on recognition of the upper or lower apparent yielding point

V1 in [N/s], [N/min], [N/mm²/s] (if test rate V1 >= V2 in [mm/min])

V2 → V3 on recognition of apparent yielding point and increase of the force to >= 1.03 F(ReH)

2.6.3 Yield stress criteria

The following criteria are applied to the load-elongation-curve *F = f(dL)* in order to determine the yield limits. If the first one does not lead to the detection of a yield limit, the next one will be applied, in the order you see below.

1. **Local load maximum, local load minimum**

A local load maximum is a yield limit, if the force drops with at least 0.5%, and then increases again with at least 1%.

2. **Local load maximum, point of inflexion**

   A local load maximum is a yield limit, if the force drops with at least 0.5%, followed by a point of reflexion in the curve (i.e. a change from falling direction to increasing direction).

3. **Load plateau**

   If a range with constant load is found while elongation increases, the beginning of this range represents a yield limit. Pre-condition: The load must not deviate with more than 0.5% over a elongation range of 0.2% of the measuring length.

2.6.4 Tensile modulus limits

The tensile modulus limits can either be detected automatically or pre-defined by the user.

Automatic detection: On the load-elongation-curve *F = f(dL),* within the range between pre-load F0 and maximum load FM, the software searches the steepest increase line over an elongation range of 0.2% of the measuring length L0 (normally, between 0.05% and 0.25% strain). Then, the tensile modulus Et will be calculated between the end points of this line. Whereas the tensile modulus Et can be calculated either as secant or regression line. In case the elongation range of 0.2% L0 will not produce a reasonable tensile modulus, the modulus will be calculated over a range of 10% of Fmax instead.

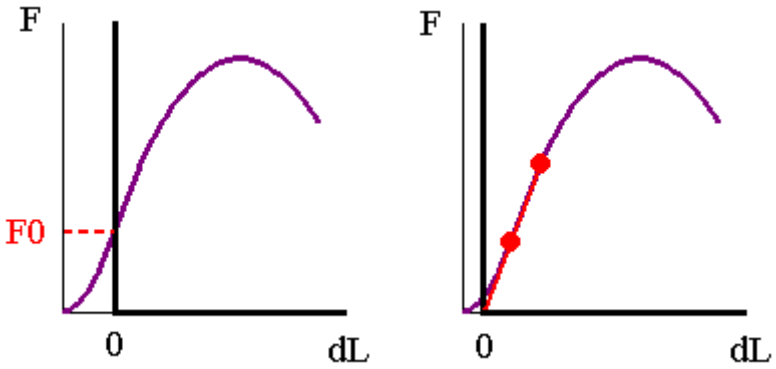
Manual detection: In case the tensile modulus should not be detected automatically, you can define the end points of the tensile-modulus-line via the input values M1 and M2 by yourself.

2.6.5 Elongation, strain

During the test: Elongation and strain are identical untill reaching the pre-load F0 = 0 (see left picture below). The elongation is the increase in length of the sample from the point F0. The strain will be calculated out of the elongation via the following formula:

$$Ax = \frac{dL(Fx) - dL(F0)}{L0} * 100\%$$

After the test: At the end of the test, elongation and strain will be calculated again. Hereby, the zero point of elongation is defined by extending the tensile-modulus-line until it reaches the x-axis in the load-elongation-diagram (see right picture below).



2.6.6 Behaviour at A Ext

The elongation/strain can be detected either via the crosshead travel or by using an extensometer. As a option, a width extensometer can be used to detect the change in sample width during the test, in order to detect the Poisson's ratio of the sample. The software offers the possibility to remove the extensometer for length as well as the one for width during the test. This happens at strain value A Ext.

When strain value Av is reached, the test can be continued in one of the following manners:

1. **Continue test:** The test will be continued in a normal manner. A Ext has no influence.
2. **Stop test:** The test will be stopped at reaching A Ext.
3. **Pause test, drop extensometer:** The test will be interrupted. Now, the user can remove the clip gauge before continuing the test. An automatic extensometer will be removed automatically before the test continues.
4. **Continue, drop extensometer:** The test will not be interrupted. A message will inform the user about the possibility to remove the clip gauge. However, the test will continue during removing. An automatic extensometer will be removed automatically during the test.

Note: Please note that the tensile characteristics of plastics do very much depend on the test speed. Hence, we recommend to prefereably not interrupt a test if possible!