Informal Group on gtr No 9 – Phase 2 (IG GTR9-PH2)
8th meeting, Paris/France, 9 – 10 September 2013

Possible Influence of Temperature & Humidity on the FlexPLI Behaviour

Presented by the pedestrian safety experts of the
International Organization of Motor Vehicle Manufacturers (OICA)

Opening Remark

All figures come from public papers available on chemist's BASF web sites:

- http://www2.basf.us//PLASTICSWEB/displayanyfile?id=0901a5e180004880
- http://www2.basf.us//PLASTICSWEB/displayanyfile?id=0901a5e18018060f

- Designations:

  PA= **P**oly**A**mide

  PA**6** = specific grade of PA

  Unreinforced PA = not filled plastic (no glass fibers …)

  Nylon, Ultramid = commercial names for **PA**

Abstract: Humidity & Temperature Influence on FlexPLI

- The "blue parts" are made of unreinforced polyamide PA6, with thickness areas ranging from 2 to 6 mm (see pages 6-7)

- PA6 absorbs humidity (page 8), resulting in decreased strength (E, S – page 9), but better impact energy absorption (W)

The time needed for water absorption of a 2 mm thick part, at 2% water content (average amount) is of:

- 2 days immerged in a 20°C water or
- 100 days in climate chamber (23°C, 50% relative humidity) (page 14); or
- 2 hours immerged in a 80°C water (extrapolation page 15)

For a thicker part (4 to 6 mm):

- 1 day immerged in a 70°C water

Conclusions

- Current working conditions for FlexPLI in countries with moderate climate conditions (such as Europe: 40 % to 50 % relative humidity (RH)) are ok
- Countries with more extreme weather conditions (especially tropical conditions with high humidity) should check if the humidity content alters the results (or store the FlexPLI in controlled climate chamber)
- Influence should be negligible (see pages 15 – 16)

Test Proposal for Tropical Weather Conditions

In order to measure the **influence of the humidity:**

1/ Saturate the blue parts at
« equilibrium moisture = 3,8% water content ».

Proposed procedure to saturate the blue parts:

- 1 day immerged in a 70°C water
- Followed by 1 week in climate chamber (23°C, 50% HR) to make "uniform % of the water" in all the different thicknesses areas
- Then assemble the FlexPLI (no need to do this quickly since the sensitivity to air humidity is low)

2/ Test the FlexPLI with the «moisturized» blue parts

THANKS

Questions?

See next pages for more detailed explanations

For detailed questions please refer to the author, Ms. Irina DAUSSE / Renault,
as representatives of the Task Force Pedestrians of the European Automobile Manufacturers' Association ACEA

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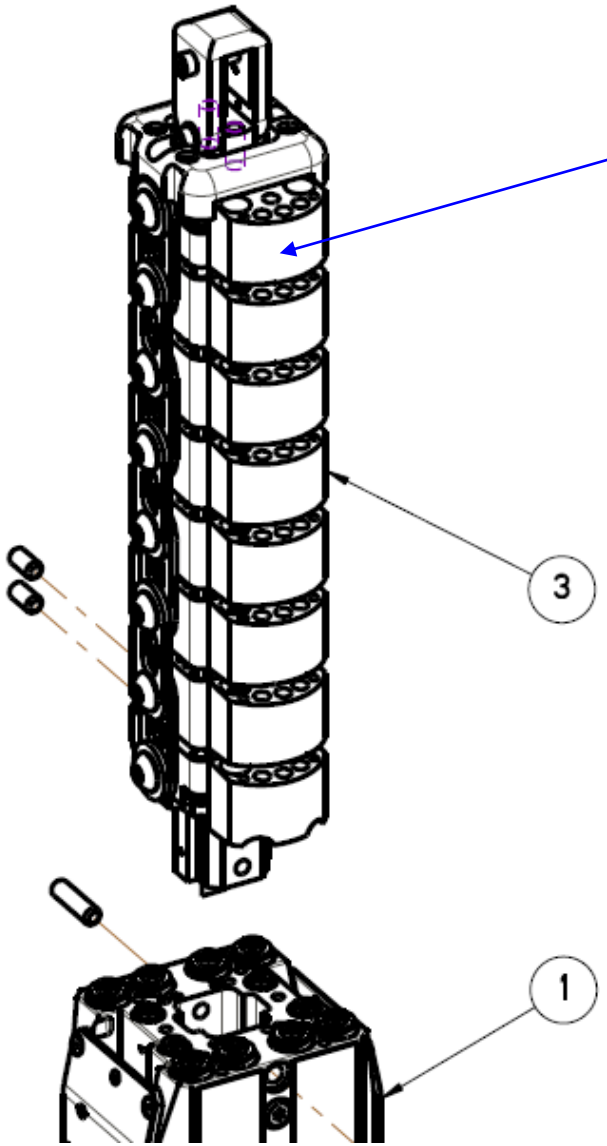
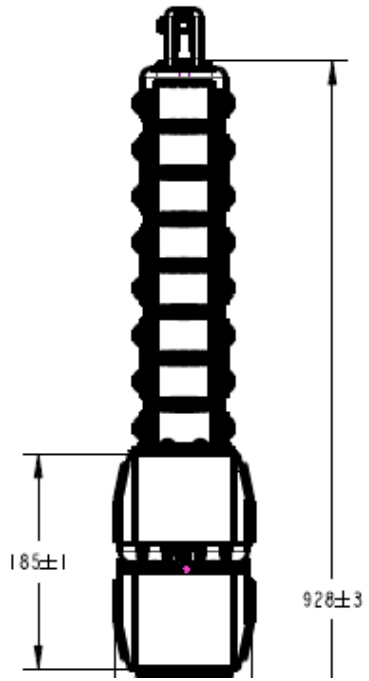
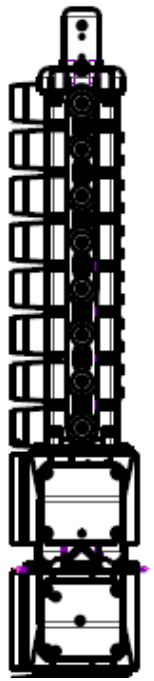
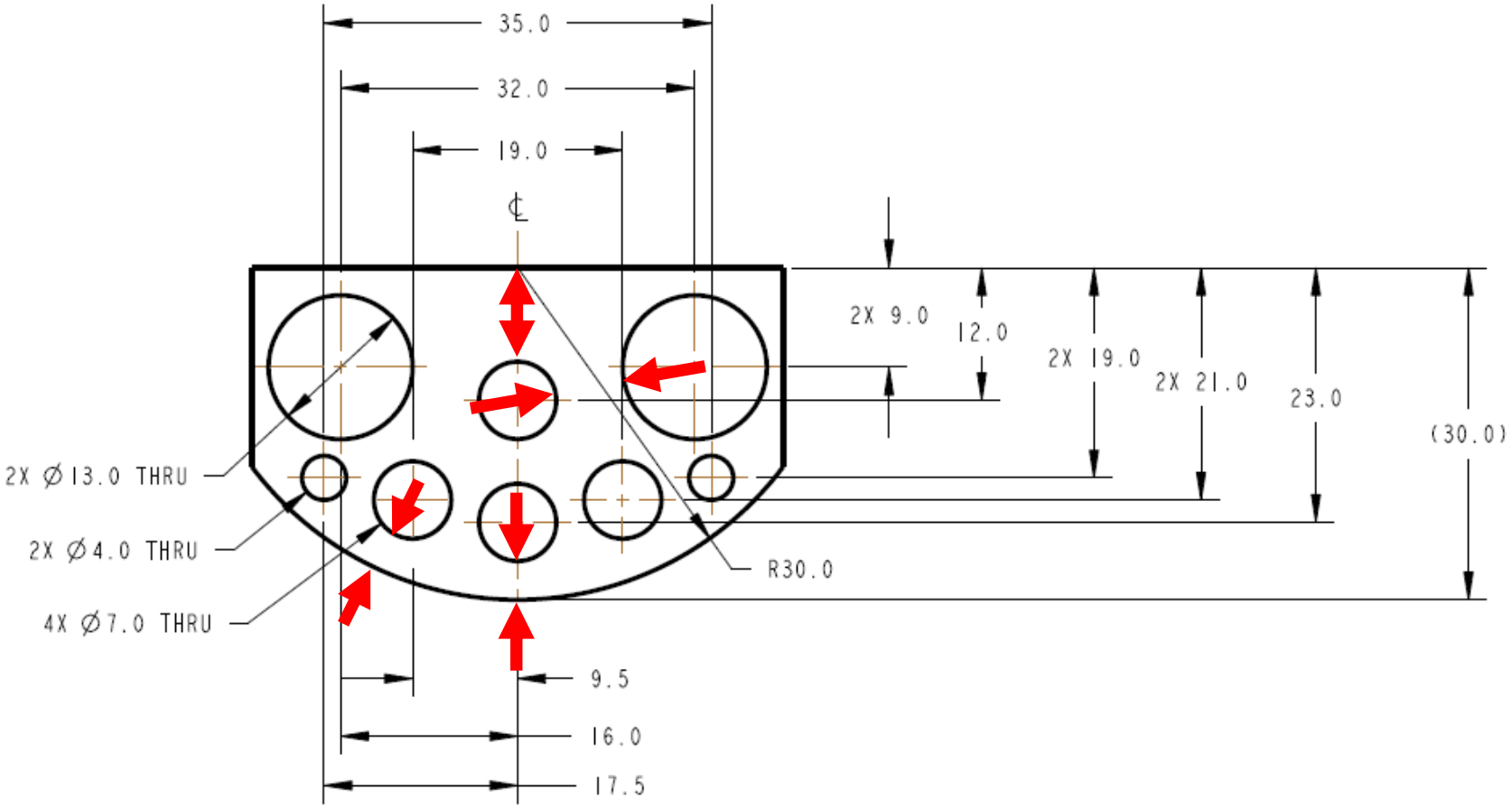
Blue parts on FlexPLI (Humanetics)







One blue part section:
« effective thickness » = red arrows



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The blue parts are made of different thickness areas.

Water Absorption and Mechanical Properties

A special characteristic of polyamides in comparison with other thermoplastics is their water absorption.

In water or in moist air (depending on its **relative humidity** and dependant on **time**, **temperature** and **wall thickness of the parts**),

PA6 parts absorb a certain quantity of water so that:

- ✓ their dimensions increase slightly,
- ✓ and their mechanical properties change:
  - decreased strength,
  - but better impact energy absorption.

Water Absorption for Different Plastics

Table 2. Water Absorption Values for Selected Thermoplastics after 24 h. (ISO-62, ASTM D570) [6]

Material	Water Absorption
PP	< 0.01 %
PC	0.15 %
Nylon 11	0.25 %
Nylon 6	1.3 %
Cellulose Acetate	1.7 %

& weather conditions

Table 3. Influence of Relative Humidity on Water Absorption in Non-Filled Nylons (at 23°C in air) [7]

Type of PA	30% RH	50% RH	62% RH	100% RH
PA 46	1.4%	3.8%	5.0%	15%
PA 6	1.1%	2.75%	3.85%	9.5%
PA 66	1.0%	2.5%	3.6%	8.5%

Europe

Tropical areas

Standardised Humidity Tests

ISO-291 defines the following two **<u>standard atmospheres</u>** for conditioning:

- "**Atmosphere 23**":

  23/50 (temperature in °C/ relative humidity in %),

  recommended **for most applications**;

- "**Atmosphere 27**":

  27/65, recommended **for tropical regions**.

Effects of water absorption

water absorption results in :

(+) increased impact strength, elongation at break and tendency to creep

whereas

(-) strength, rigidity and hardness decrease.

The blue parts: have to absorb energy, but not to break during the test.

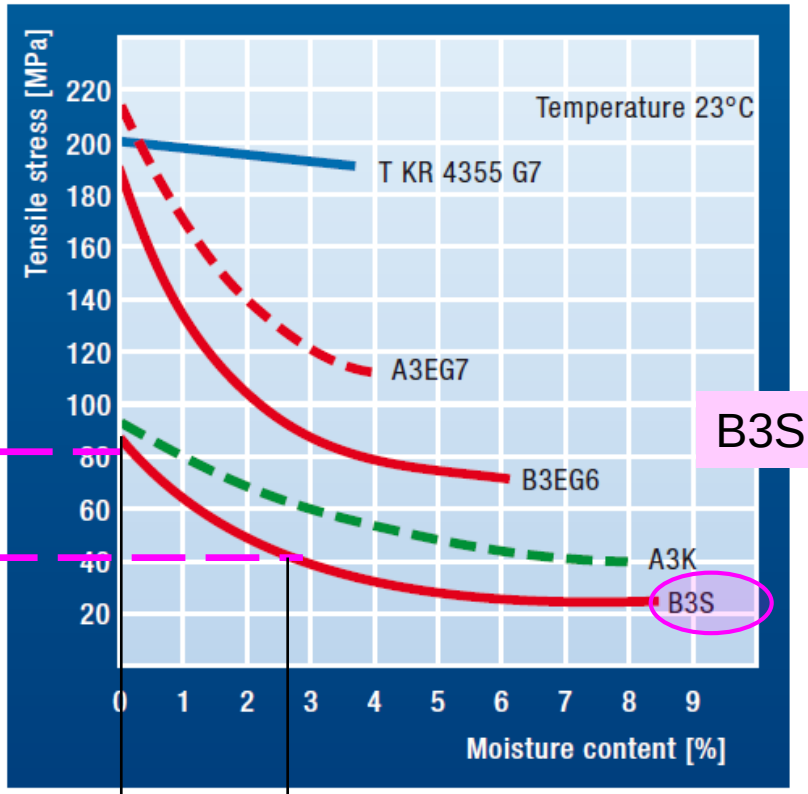

Fig. 3: Tensile stress (yield stress in the case of unreinforced grades) for Ultramid® as a function of moisture content at 23°C (ISO 527)

B3S = unreinforced PA6

S= 80MPa at 0% moisture

S= 40MPa at 2,75% moisture

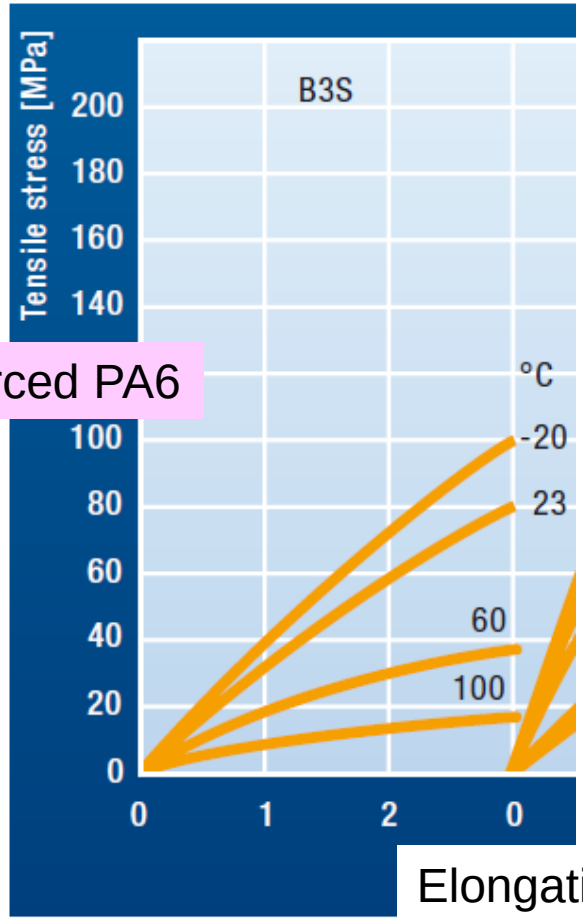

Fig. 9: Stress-strain diagrams for B3S (dry) / ISO 527 (test speed 2 mm /min)
= low speed tensile test

➢ Humidity has a great influence on the mechanical properties, T° only a « minor » one.

NOTE: These values are for glass fiber filled PA6 only!

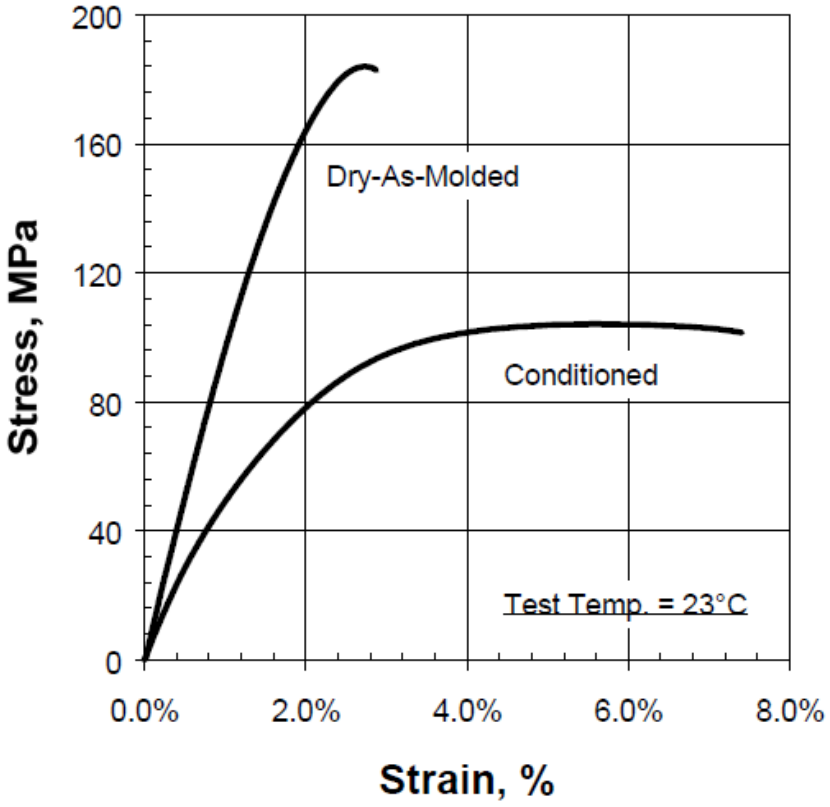

Figure 2b. Effect of moisture on tensile behavior of reinforced nylon 6 (33% glass fiber) at room temperature.

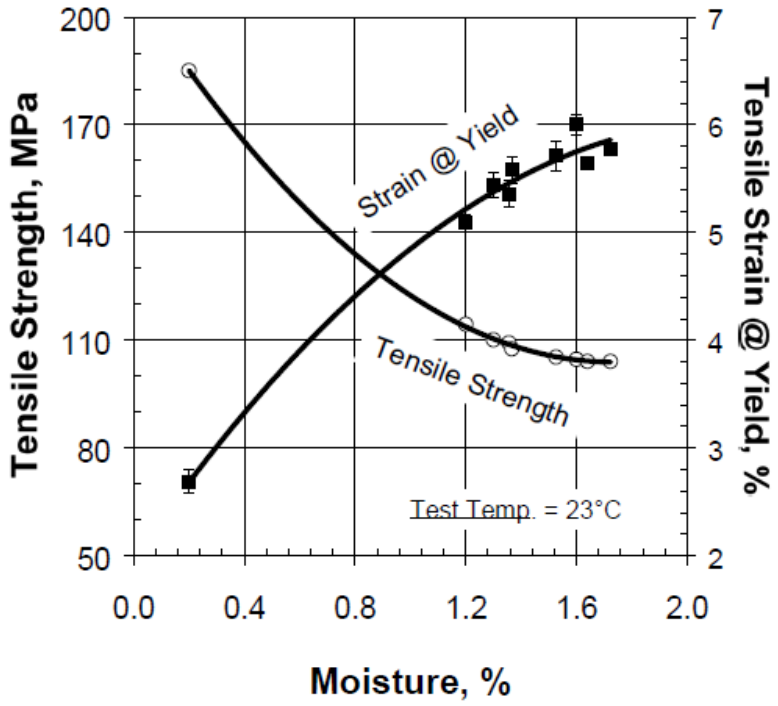

Figure 3. Effect of moisture on tensile properties of reinforced nylon 6 (33% glass fiber): tensile strength and strain at yield vs. moisture at room temperature.

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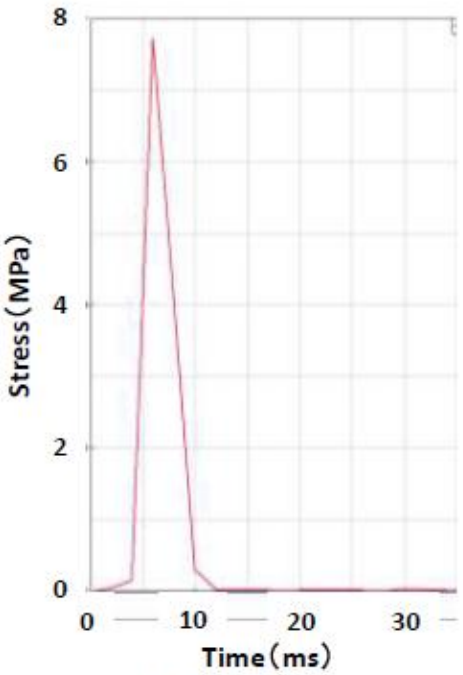
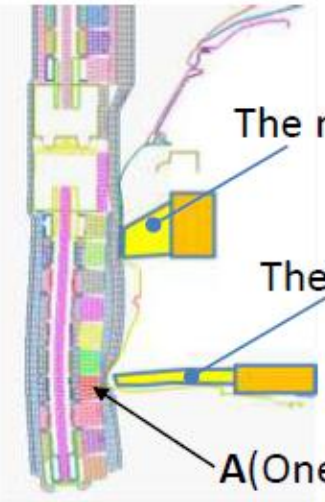
Stress which occurs in the “blue parts” at the time of a test



Stress which occurs in **A**



The maximum generating load: 5kN

The maximum generating load: 6kN

A(One of the “blue parts”)

The maximum stress occurred at **A**.

The stress of the maximum which occurs in the blue parts is about 10 MPa.

Positioning to humidity influence

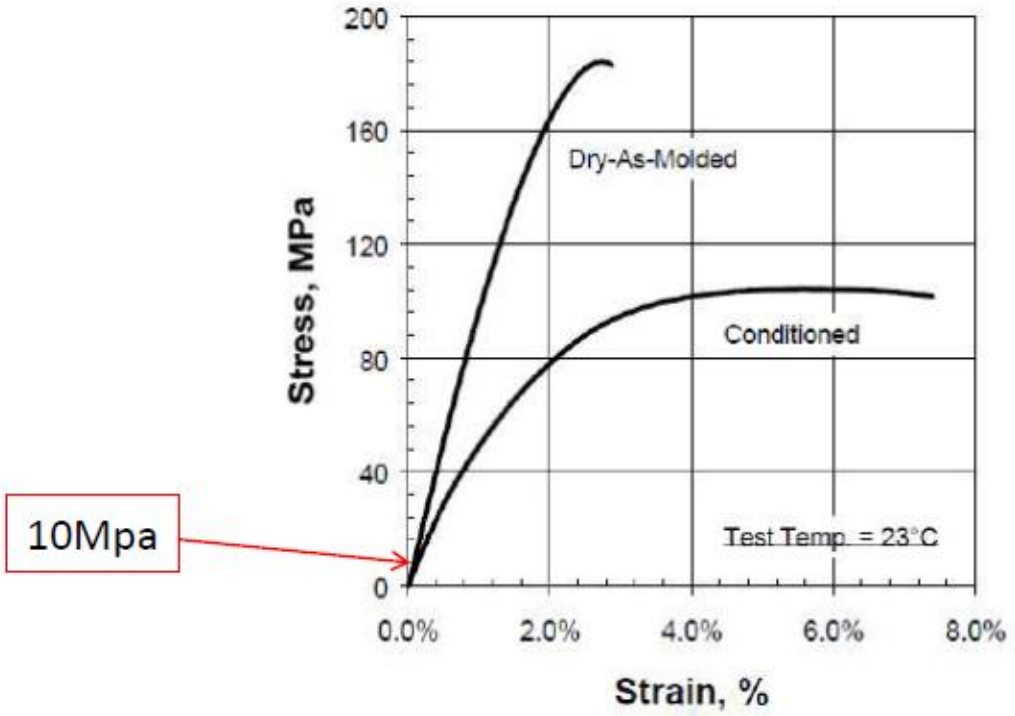


Figure 2b. Effect of moisture on tensile behavior of reinforced nylon 6 (33% glass fiber) at room temperature.

Low Sensitivity
No need to control

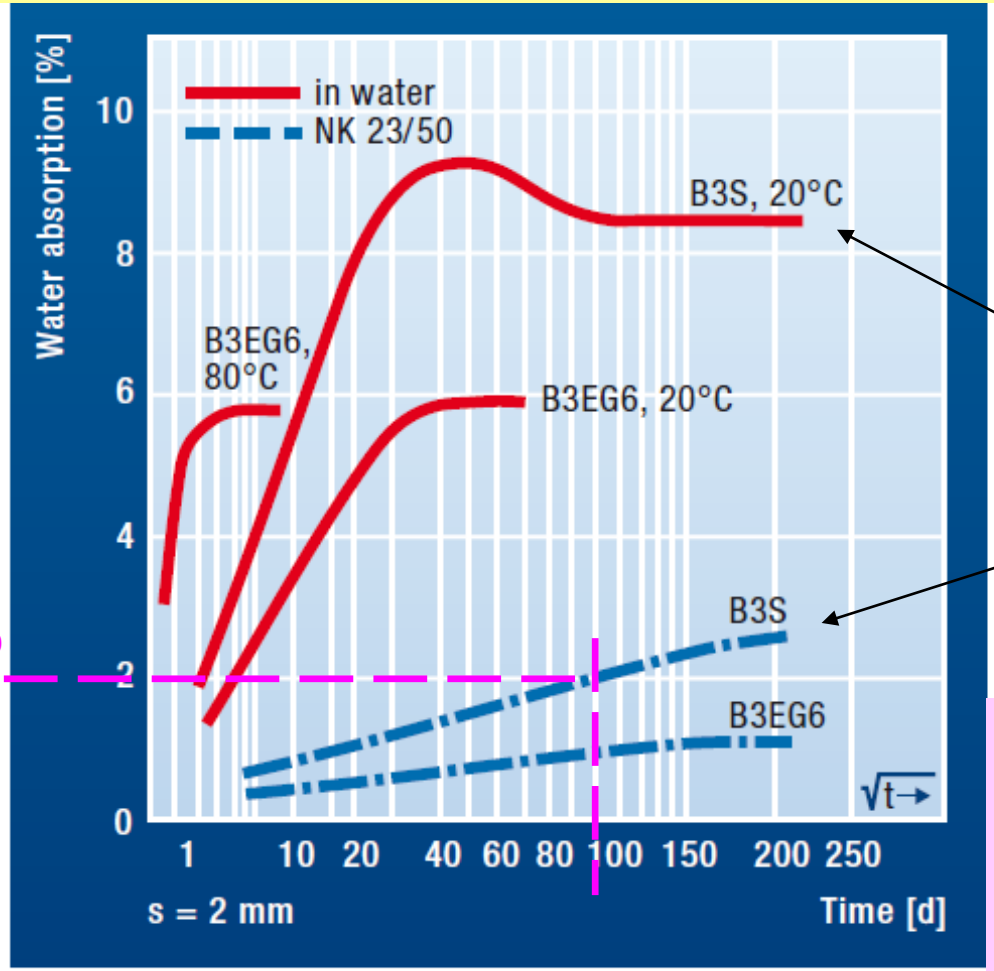


Fig. 20: Water absorption of Ultramid® B as a function of storage time and the conditioning parameters (specimen thickness 2 mm)

Same part (2mm thick)
Red = in water, 20°C

Blue= in climate chamber
(23°C, 50% relative humidity)

If we consider « working conditions » at around 2% water absorbtion
⇒**100 days in climate chamber…**

⇒**…and 2 days in water …**

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http://www2.basf.us//PLASTICSWEB/displayanyfile?id=0901a5e18018060f

Figs. 20-21 show the water absorption of Ultramid® as a function of storage time under various test conditions. It is evident from these that in comparison with the PA 6 and PA 66 grades Ultramid® T affords distinct advantages with respect to water absorption.

As can be seen from the Ultramid® range chart, water absorption results in increased impact strength, elongation at break and tendency to creep whereas strength, rigidity and hardness decrease.

Provided that the water is uniformly distributed in the molding, Ultramid® A and Ultramid® B undergo a maximum increase in volume of about 0.9% and a mean increase in length of 0.2% to 0.3% per 1% of absorbed water. The dimensional change of the glass-fiber

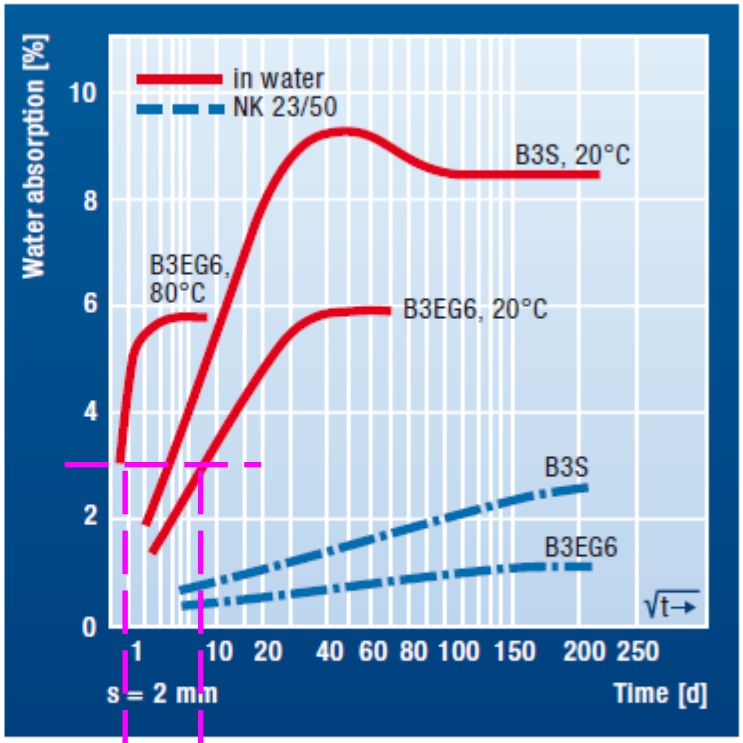

Fig. 20: Water absorption of Ultramid® B as a function of storage time and the conditioning parameters (specimen thickness 2 mm)

For the same PA6 grade (B3EG6):
To get 3% water content in a 2mm thick part immerged in water:

⇒ **half a day if 80°C water**

⇒ **nearly 10 days if 20°C water**

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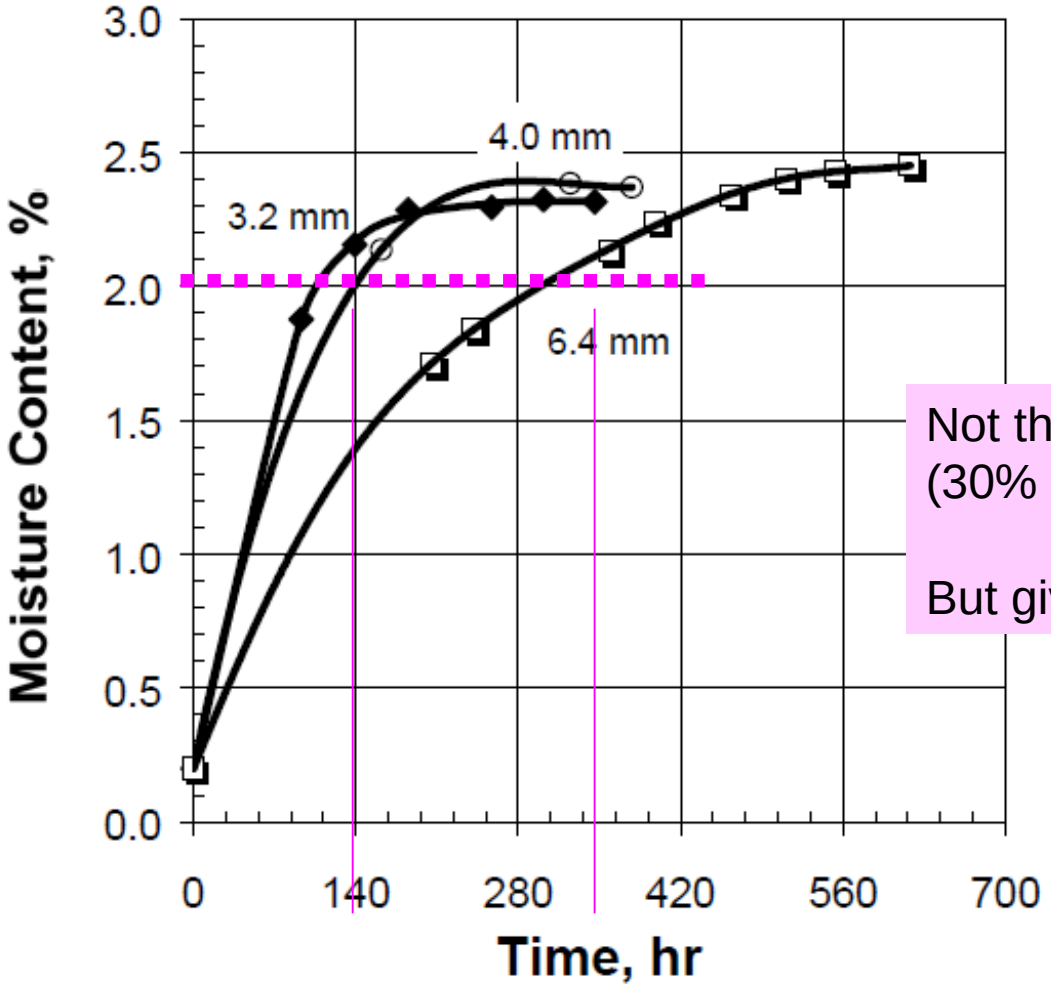

Not the good material
(30% glass fiber filled)

But gives a good indication !

Figure 1. Moisture absorption vs. time for 33% glass fiber reinforced nylon 6. The number in mm by each curve indicates the thickness of the samples [5].

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Europe conditions:

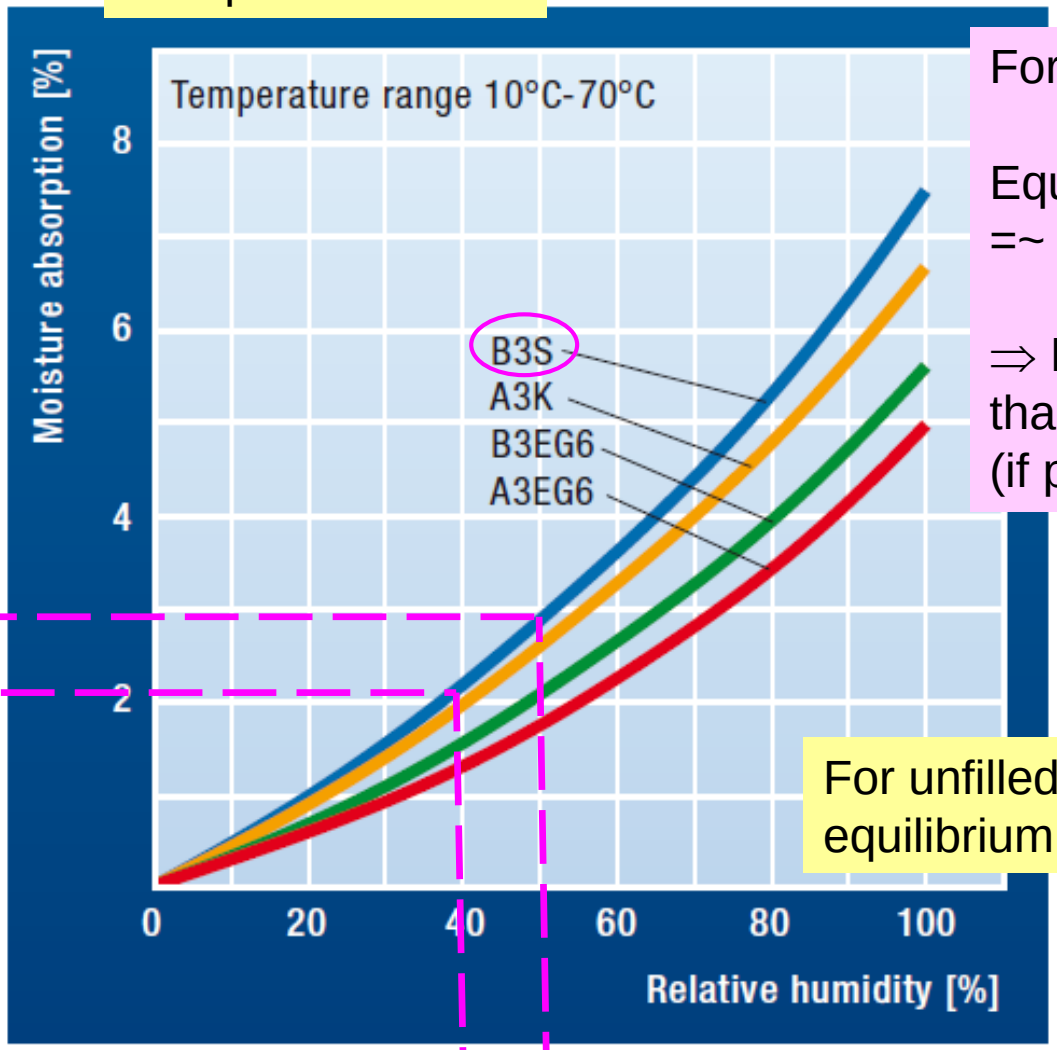

Fig. 19: Equilibrium moisture content of Ultramid® as a function of relative humidity in the temperature range 10°C - 70°C (scatter: ± 0.2 to 0.4% absolute)

For unreinforced PA6 (see B3S):

Equilibrium moisture
=~ 3% water at 50 % HR

⇒ For the FlexPLI, it could be more than 2 % water at 40 % HR
(if properly stored in climate chamber)

For unfilled PA6, the moisture at equilibrium at 23°C and 50 %RH is 2.75 %

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