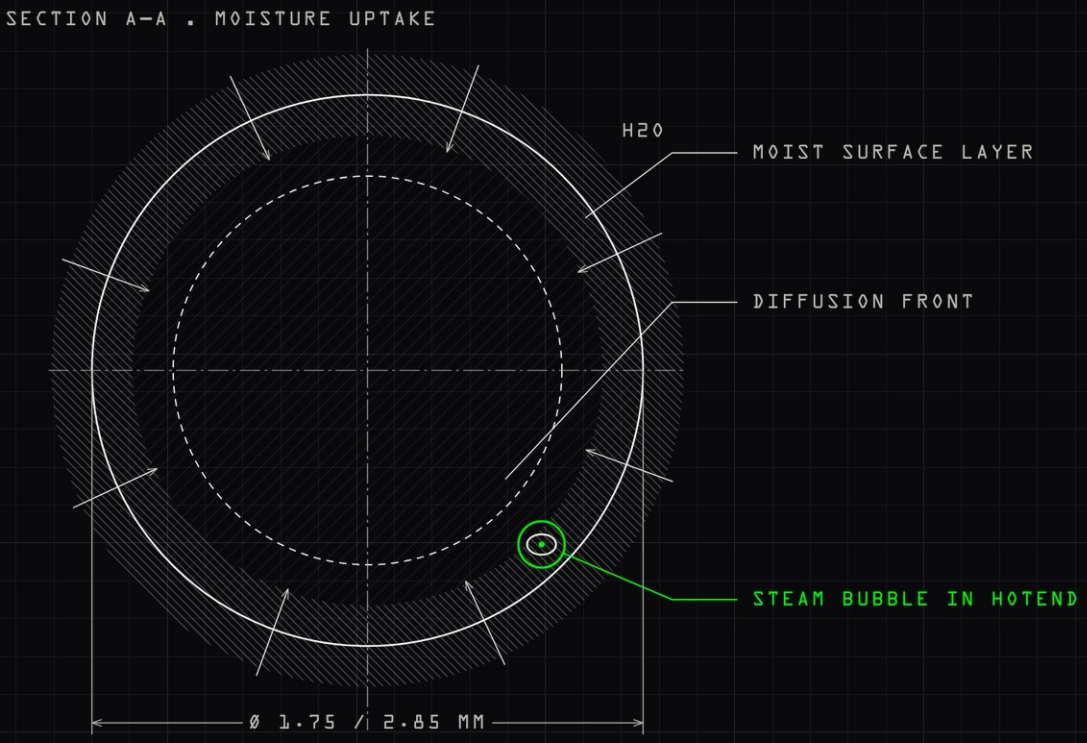
FIBERTHREE



WHITE PAPER . WP002

MOISTURE IN THE FFF PROCESS

How strongly does moisture affect printing with polyamide, and how long does a filament need to dry? With a test series on F3 PA-CF Pro.

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WP002

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00 . EXECUTIVE SUMMARY

Moisture is one of the most common reasons for poor FFF prints. Hygroscopic filaments such as polyamide absorb water from the room air. In the hotend this leads to bubbles, uneven extrusion, poor layer adhesion and dimensional deviations.

Our test series with F3 PA-CF Pro shows: spools stored openly at 20.5 °C and 31.7 % relative humidity absorbed about 0.32 % of their weight in water within four days, half of it on the first day. In a drying oven at 75 °C most of it came out again on the first day; after four days the filament was as dry as it gets.

AT A GLANCE

- **Dry** in a heated drying oven at 75 °C for as long as the spool was open, 4 days if the duration is unknown
- **Keep dry** during printing in an airtight box, re-dry from 30 % relative humidity
- **Sealed Fiberthree spools** are dried at the factory and can be printed directly
- **A few printers** can be supplied cost-effectively and locally with an in-line dryer such as Drywise

Recommendation: Dry centrally in a drying oven at 75 °C and feed the printer from an airtight box.

0.32 %	52 %	4 days
Water uptake in 4 days, open spool	of it on the first day	Oven drying until the plateau

01 BACKGROUND

Dry filament is the prerequisite for good FFF parts. Hygroscopic plastics such as polyamide (PA), PC, TPU, PVA and PEI absorb moisture from the ambient air, and do so within hours.

In the hotend the bound water evaporates abruptly. The filament swells, extrudes unevenly, forms bubbles and adheres less well to the previous layer. The part becomes weaker and less dimensionally accurate. PLA and PP are considerably less hygroscopic and are not the focus of this paper.

Two tasks need to be distinguished:

- **Drying:** actively removing moisture from the filament before printing.
- **Keeping dry:** preventing the filament from taking up moisture again during storage and printing.

This paper shows how strongly moisture affects printing, compares central and local drying and gives specific drying times. The recommendations are based on our own test series with F3 PA-CF Pro. WP002 is part of our white paper series, which begins with the material overview in WP001. It is followed by WP003 on post-processing parts and WP004 on design for manufacturing.

FIG. 1: SCHEMATIC

SECTION A–A . MOISTURE UPTAKE

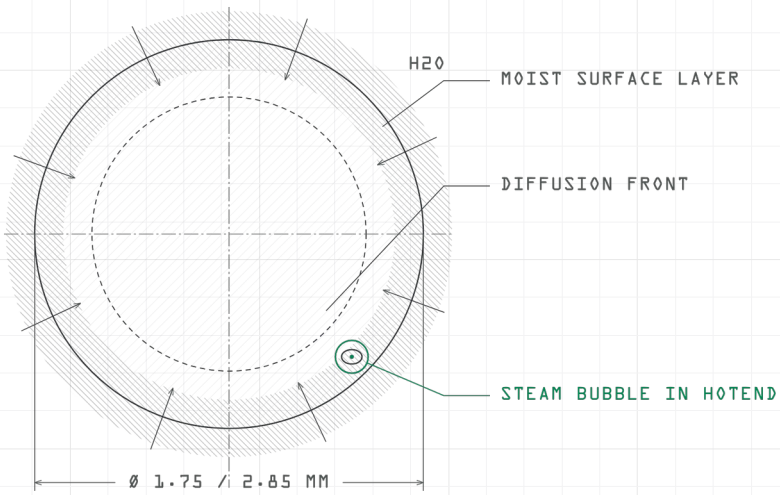


FIG. 1 Filament cross-section with moist surface layer and diffusion front, schematic, not to scale.

02 MOISTURE AND PRINT QUALITY

Moist filament is immediately visible on the printed part. Figure 1 shows two pairs of test parts, each printed with dried filament on the left and undried filament on the right.

FIG. 2: MOISTURE AND PRINT QUALITY

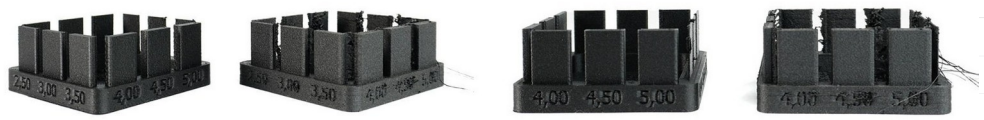


FIG. 2 Two pairs of test parts. Left in each case printed with dried filament, right with undried filament.

The undried parts show the typical defects:

- **Surface defects:** rough, bubbly surfaces and stringing between the ribs
- **Uneven extrusion:** gaps and frayed edges on thin walls
- **Dimensional deviations:** thin ribs and lettering become unclean and deviate from the nominal size
- **Poorer layer adhesion:** steam bubbles disturb the bond between the layers

Moisture affects more than appearance and dimensions. Mechanical properties such as tensile strength and modulus also drop, because bubbles and weak layer boundaries reduce the load-bearing cross-section.

DISTINGUISHING FILAMENT AND FINISHED PART

Moisture in the **filament** is harmful during printing and must be removed beforehand. The **finished part** made of polyamide then takes up moisture from the environment again, and that is intended: only then does it become tough. WP003 describes in the section on conditioning how this process can be controlled.

03 WAYS TO DRY

How to dry depends mainly on how many printers there are and where they are located. Figure 2 shows the three ways a spool reaches the printer dry at our facility:

- **Blue:** a sealed Fiberthree spool goes directly into the dry box at the printer. We dry the spools before sealing them.
- **Green:** central drying in a heating oven, then keeping dry in the F3 Safe Light dry box at the printer.
- **Yellow:** local drying with a Drywise in-line dryer directly at the printer.

FIG. 3: WAYS TO DRY



FIG. 3 Ways to dry filament. Blue: sealed spool directly into the dry box. Green: centrally in a heating oven, then F3 Safe Light dry box. Yellow: locally with a Drywise in-line dryer.

	CENTRAL DRYING	LOCAL DRYING
Principle	Dry and store all spools in one place, keep them dry at the printer	Dry each spool directly at the printer
Equipment	Heated drying oven, vacuum drying oven, alternatively a food dehydrator or oven; at the printer F3 Safe Light or F3 Safe Long Run	In-line dryer, e.g. Drywise
Suitable for	Many printers at one site	One or two printers, or printers at different locations
Advantages	Many spools at once, immediately ready for use, also for long-term storage	Low-cost entry, spool does not need to be dried beforehand
Disadvantages	Investment in a drying oven	Lead time up to 45 minutes, the path to the extruder can be difficult depending on the material

TAB. 1 Ways to dry.

CENTRAL DRYING

Heated drying ovens reliably reduce the moisture content and keep the spools dry until use. At 75 °C a spool is sufficiently dry after four days, depending on its initial moisture (Chapter 05). Higher temperatures shorten drying but can impair the mechanical properties of the filament. Vacuum drying ovens work at lower temperatures because the boiling point of water drops in a vacuum.

At the printer the filament must then stay dry. For this there are the airtight dry boxes F3 Safe Light and F3 Safe Long Run, through which the filament runs directly to the printer.

The drying oven has a second use: printed parts made of F3 PA-CF Pro can also be annealed in it at 75 °C (WP003).

LOCAL DRYING

The Drywise system dries the filament in-line, just before it enters the print head. Hot, dry air flows over the filament. Programs are stored for F3 PA-CF Pro and F3 PA-GF30 Pro. The path between dryer and extruder can be difficult depending on the plastic, because the warm filament can break or stretch there.

04 DRYING GUIDELINES

We recommend central drying in an actively heated drying oven at 75 °C and an airtight dry box at the printer. The drying time depends on how long the spool has been open:

CASE	DRYING TIME AT 75 °C
New Fiberthree spool, seal intact	Printing without drying is possible. For best results or if storage is unclear, up to 24 h
Spool was outside the drying oven for a known time	the same time it was open
Spool was open for an unknown time	4 days
Local drying with Drywise	no pre-drying needed

TAB. 2 Drying guidelines.

We dry all spools before sealing them. As long as the seal is intact, the filament stays dry.

TEMPERATURE

75 °C is our recommendation for the polyamides. Higher temperatures shorten drying but can impair the mechanical properties of the filament.

CHECKING DRYNESS

The times in the table are guide values. A scale is more precise: weigh the spool before and during drying. At first the weight drops quickly, then it approaches a constant value. Once the weight is stable, the spool is dry.

KEEPING DRY

- **During printing:** feed the filament from an airtight box, such as F3 Safe Light or F3 Safe Long Run.
- **Watch the hygrometer:** if the hygrometer in the box shows more than 30 % relative humidity, take the spool out and actively re-dry it.
- **Longer print breaks:** store the spool in the drying oven, not openly at the printer.

The scale is the most reliable checkpoint. It not only shows when a spool is dry but also makes visible how quickly a spool takes up moisture in your own environment. Documenting this once for your spool sizes lets you adapt the drying times to your own conditions.

A fixed routine is important: spools go back into the drying oven or the dry box after printing, keep an eye on the hygrometer, and when in doubt re-dry rather than risk a faulty print.

05 RESULTS OF THE TEST SERIES

To quantify the effect of storage, we examined spools of F3 PA-CF Pro in four sizes: 200 g, 500 g, 1,000 g and 2,000 g. The spools were stored openly in room climate, on average at 20.5 °C and 31.7 % relative humidity. Both values remained almost constant during the test. The weight was recorded daily. After several days the spools went into a heated drying oven at 75 °C, again with daily weighing.

FIG. 4: RESULTS OF THE TEST SERIES

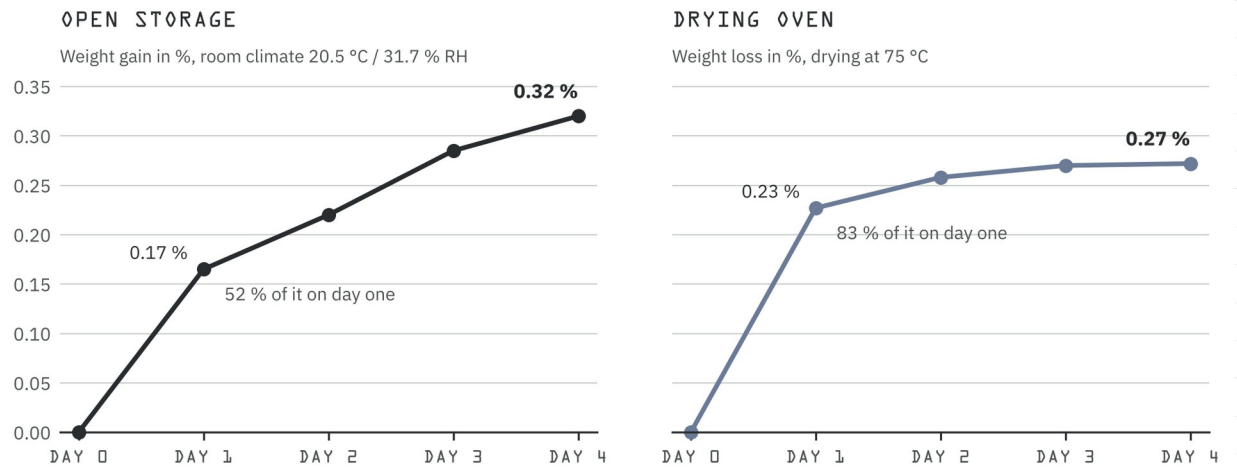


FIG. 4 Fiberthree test series with F3 PA-CF Pro: weight gain during open storage and weight loss in a drying oven at 75 °C

In room climate the spools continuously absorbed water, about half of it within the first 24 hours. After four days the uptake was not yet complete.

In the drying oven they lost most of it on the first day. After that the curve flattened and reached a plateau after four days; the filaments were as dry as they get. The drying times in Chapter 04 are derived from this.

So even a short time in room air is enough for polyamide to take up measurable moisture, even in the comparatively dry air of the test. Active drying and controlled storage are therefore the basis for consistently good prints.

06 CONCLUSION

Even in comparatively dry room air, polyamide takes up measurable moisture within a day. Active drying and controlled storage are therefore the basis for consistently good prints: dry in a drying oven at 75 °C, check with a scale and feed the printer from an airtight box.

> "A short time in room air is enough for polyamide to take up measurable moisture."
>
> — Result of the Fiberthree test series with F3 PA-CF Pro

REFERENCES

[1] Fiberthree GmbH: Test series on moisture uptake and drying of F3 PA-CF Pro (spool sizes 200 g to 2,000 g)

[2] Fiberthree GmbH: WP002 – Effect of Moisture on Polymers in the FFF Process, previous edition (German and English)

ABOUT FIBERTHREE

Fiberthree develops and produces technical filaments for FFF printing in Darmstadt, with polyamide at the heart of the portfolio. The ecosystem includes build plates for Prusa, Raise3D and Bambu Lab as well as the F3 Safe Light and F3 Safe Long Run dry boxes. Building on our background as an engineering office, we also offer engineering, training and contract manufacturing on more than 30 printers, from first sample to small series.

WHITE PAPER SERIES

All white papers are available at www.fiberthree.com. We update the series regularly; the latest version applies.

NO.	TOPIC	HELPS WITH
WP001	Plastics for the FFF Process: Material Overview and Process Comparison	Choosing material and process
WP002	**Effect of Moisture on Polymers in the FFF Process (this paper)**	**Drying filament and keeping it dry**
WP003	Annealing and Post-Processing of FFF Parts	Annealing, conditioning, finishing
WP004	Design for Manufacturing in the FFF Process	Designing parts for FFF
WP005	Heat-Setting Threaded Inserts in FFF Parts	Detachable screw connections
WP006	Nozzle Selection for Filled Filaments	Nozzle material and diameter
WP007	Print Bed and Adhesion	First-layer adhesion
WP008	Electrostatic Dissipative (ESD) Parts in FFF Printing	Printing and testing ESD parts
WP009	Interlayer Adhesion in the Build Direction: Nozzle Temperature, Print Speed and Hotend	Strength in the z direction

TAB. 3 Overview of the Fiberthree white papers.

FIBERTHREE

START WITH THE RIGHT MATERIAL

ADDRESS

DARMSTADT

FIBERTHREE GMBH
OTTO-HESSE-STR. 19
64293 DARMSTADT

CONTACT

PHONE

+49 6151 734 75 900 .
FIBERTHREE.COM

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