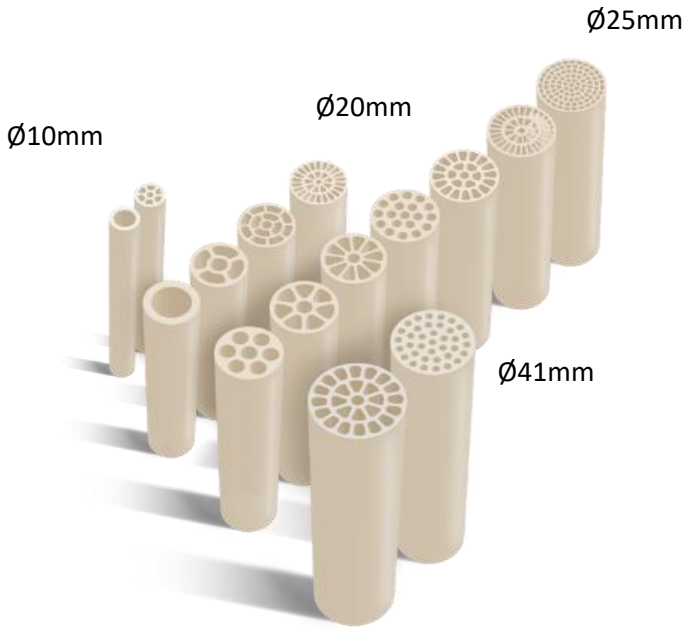
Eco-efficient ceramic membranes

Introduction

Straight channels
Current range

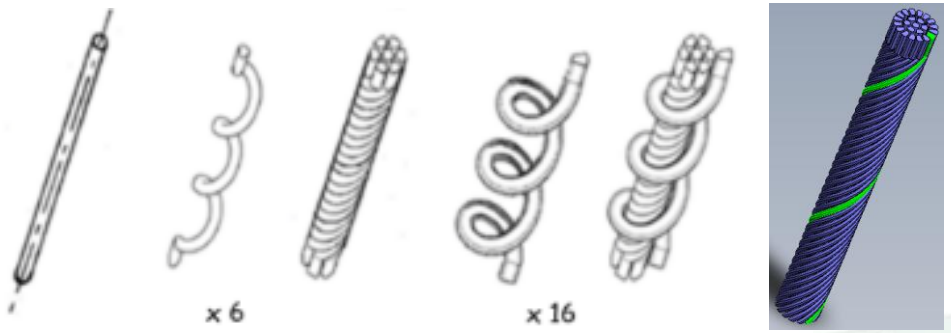


ICIM 2018
Dresden

Helicoidal channels twisted around a central channel that remains straight

Produced by additive manufacturing

Example for Ø25mm - 23 channels:



MemPro 7 2022
Montpellier

… reduction of the number of twisted helicoidal channels without central channel…

Willingness to innovate and investment effort in 3D printing

- The investment effort of TAMI Industries is significant
- It translates concretely into R&D results, 11 international patents solely focused on new shapes and processes for their manufacturing
- This effort was particularly noticed by the European Patent Office (EPO) in a press release dated July 13, 2020
- It is currently underway…

TAMI Industries quoted by the European Patent Office in a press relase dated July 13, 2020

Europäisches Patentamt
European Patent Office
Office européen des brevets

La France sur le podium des pays européens les plus innovants en matière d'impression 3D

En France, près d'une demande de brevet sur quatre vient des PME

Les PME sont à l'origine de 23 % des demandes de brevets françaises en impression 3D. Parmi elles, des PME dont la progression dans le secteur est importante se distinguent :

Tami Industries, fabricant drômois (Nyons) de membranes céramiques, a mis au point une technologie de fabrication additive permettant d'améliorer leurs performances de filtration. Ces membranes sont utilisées dans l'agroalimentaire (filtration du lait, des boissons…) dans la biopharmaceutique et dans l'environnement (filtration des liquides de process, bains de dégraissage, effluents industriels…).

3D printing

- **It was necessary to integrate in-house design and the fabrication of FDM machines capable of printings heights of 1,320mm**

A machine with 6 print heads

for simultaneous printing →

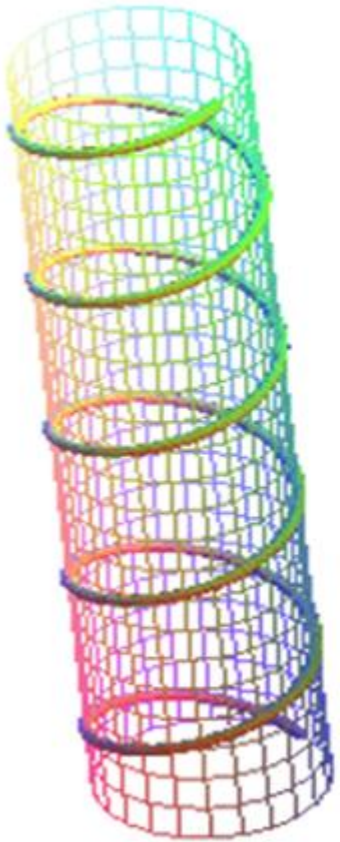
The "twist"

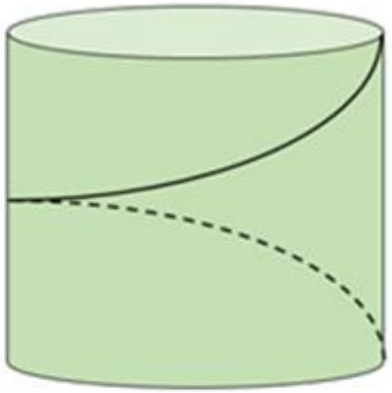
Twisted multi-channel membranes generate turbulence that reduce fouling

Initial work focused on keeping the geometries (number and shape of channels) of the existing range of membranes from TAMI Industries by twisting them.

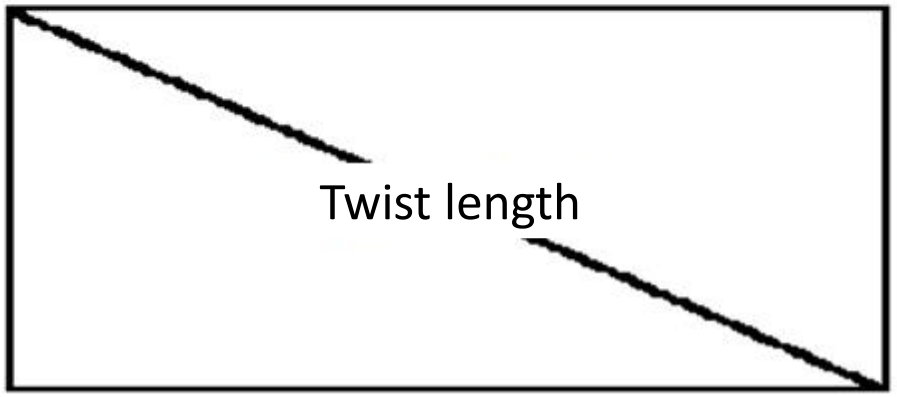
The "twist"

By principle, the twist follows a circular helix which is nothing more than a line rolled up around a cylinder of specific diameter Ø





Property of the cylinder = π x Ø



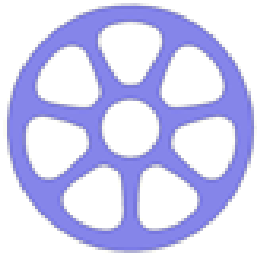
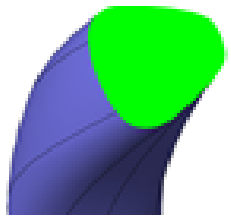
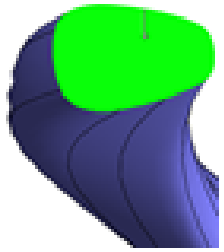
Twist length = Channel length

Twist inclination = Pitch length

Pitch

Inclination, pitch and hydraulic diameter

- Once the “twist” is created, the channel length increases and the hydraulic diameter decreases:

Exemple ø25mm-8cx				
Twist inclination angle	**90°** Linear channels	**64,5°**	**52°**	**31°**
Pitch [mm]	**-**	**132**	**90**	**57**
Dh=4A/P [mm]	**6,00**	**5,9**	**5,7**	**4,7**

In summary, the effects of the “twist” are:

↑ channel length ✚ ↓ hydraulic diameter ➡ ↑ **pressure drop**

Therefore, the new membranes with a similar design to the existing range of membranes are subject to the effects intrinsic to the presence of “twisted” channels.

⇨ **Limited range of potential use of the membranes in the industry**

⇨ **For these reasons, other alternatives were explored**

Presentation of the path chosen

Membranes with a limited number of channels were studied, manufactured and tested in two versions:

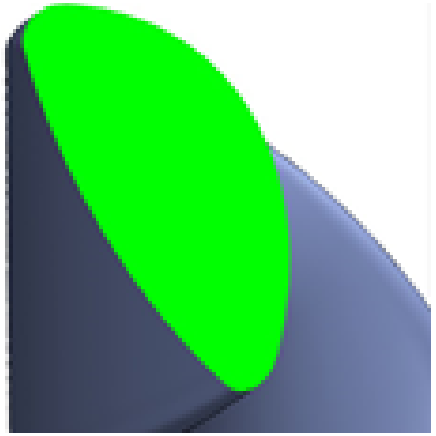
2 channel helical version 1 (**2cx-v1**)

2 channel helical version 2 (**2cx-v2**)

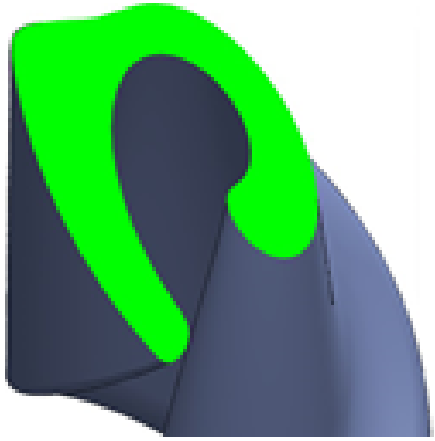
View along the cross section taken perpendicular to the longitudinal axis of the membrane

Presentation of the path chosen

Characteristic morphology of the sections perpendicular to the streamline:



2 channel helical version 1 (**2cx-v1**)

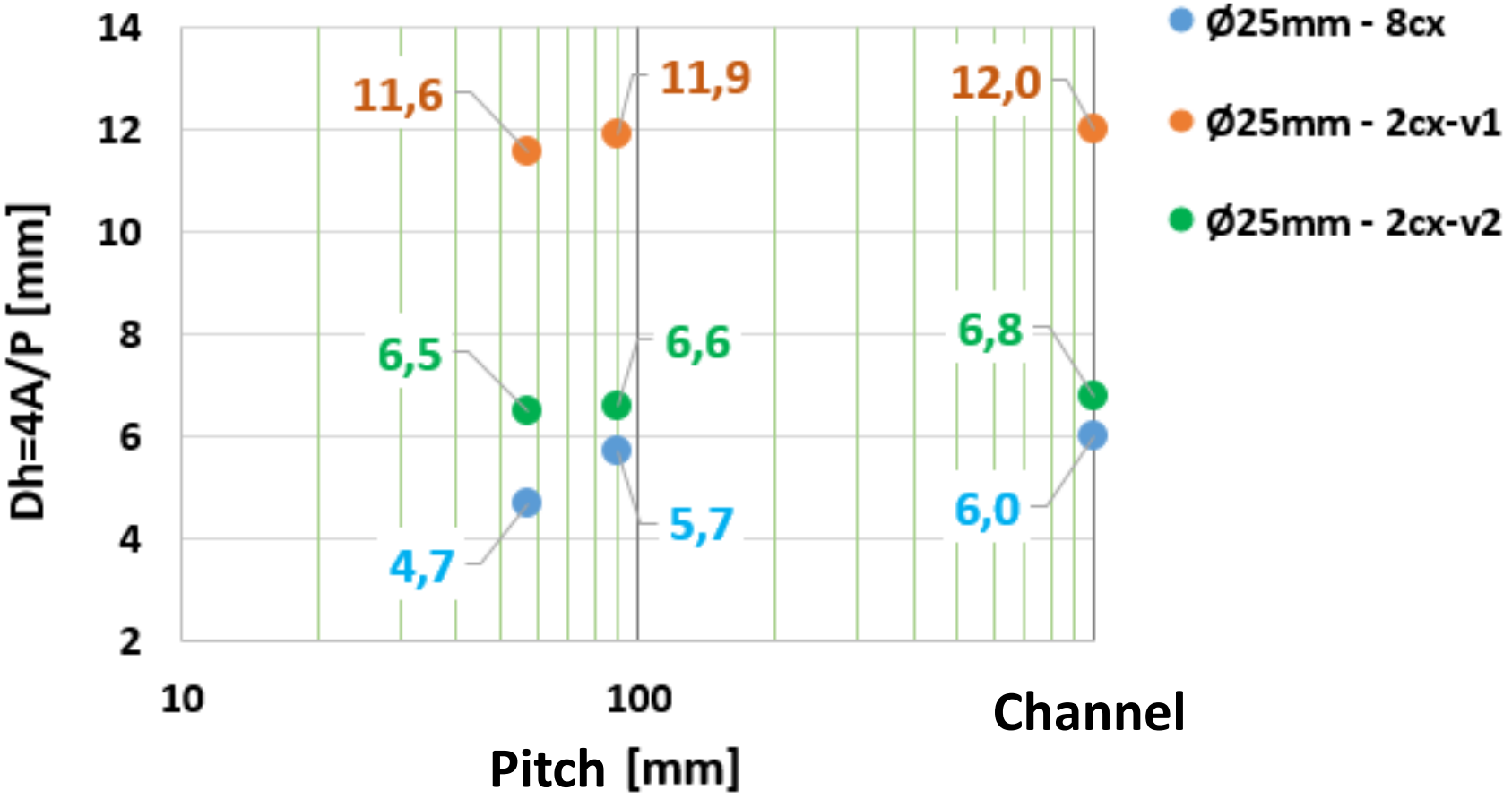


2 channel helical version 2 (**2cx-v2**)

View of 1 channel along the section perpendicular to the streamline

Presentation of the path chosen

=> Twist versions 1 and 2 show a negligeable reduction in the hydraulic Ø vs. the pitch



Legend:

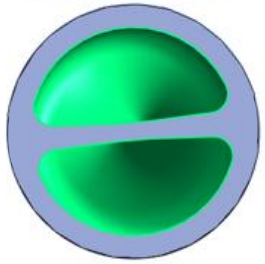
8 cx linear

2 cx-v1

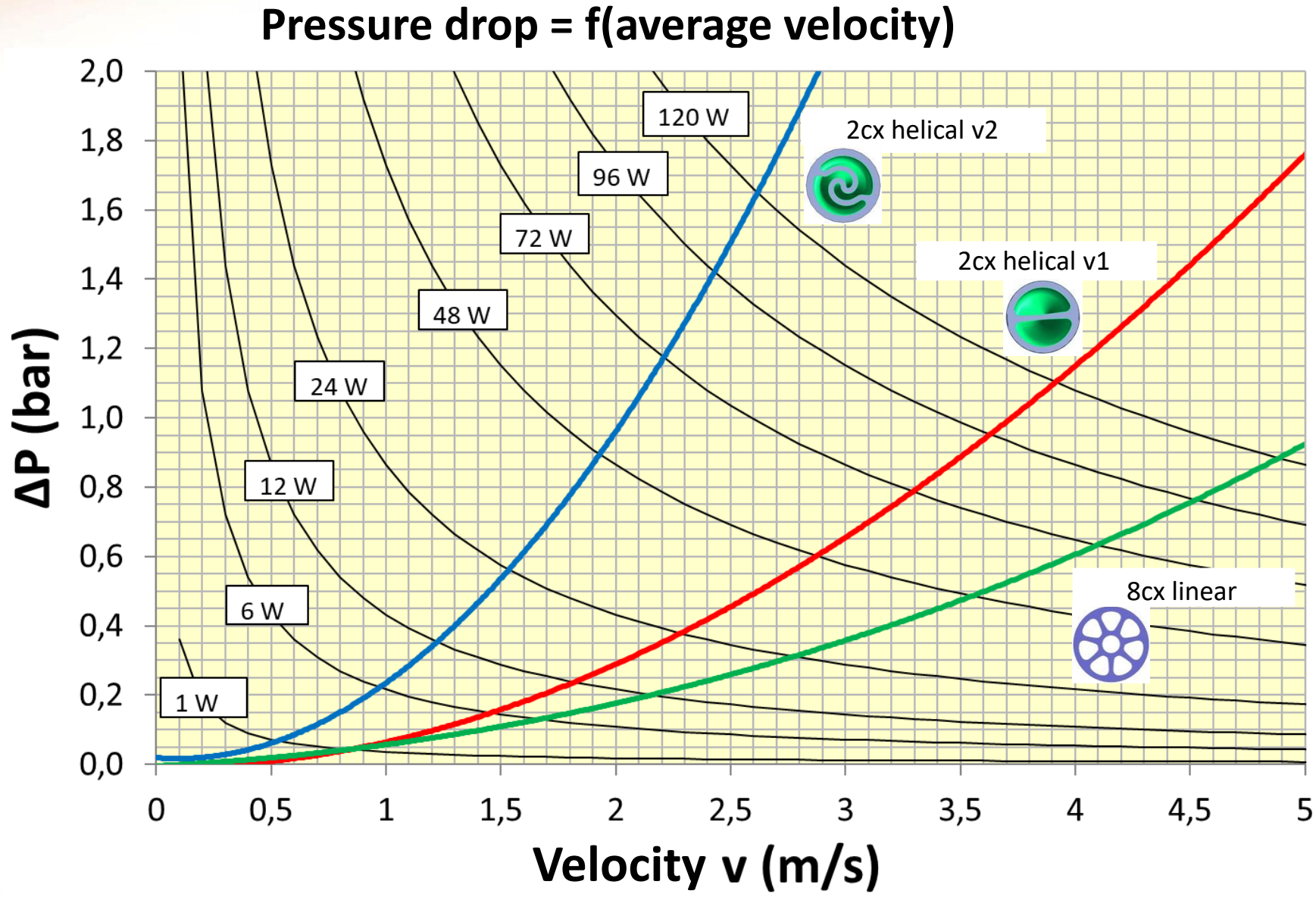
2 cx-v2

Presentation of the path chosen

Characteristics of versions 1 and 2 helical channel membranes compared to a linear 8 channel membrane:

		Hydraulic diameter [mm]	Surface [m^2]	Section [mm^2]
8cx linear		6,0	0,2	250
2cx helical v1		11,5	0,1	250
2cx helical v2		6,5	0,2	265

Presentation of the path chosen



Results on real liquid with the new shapes

Test conditions:

Liquid used: **raw wine** CDR 2021

Operation: **Fed batch** up to VCF 25

Constant feed pressure: 2 bar

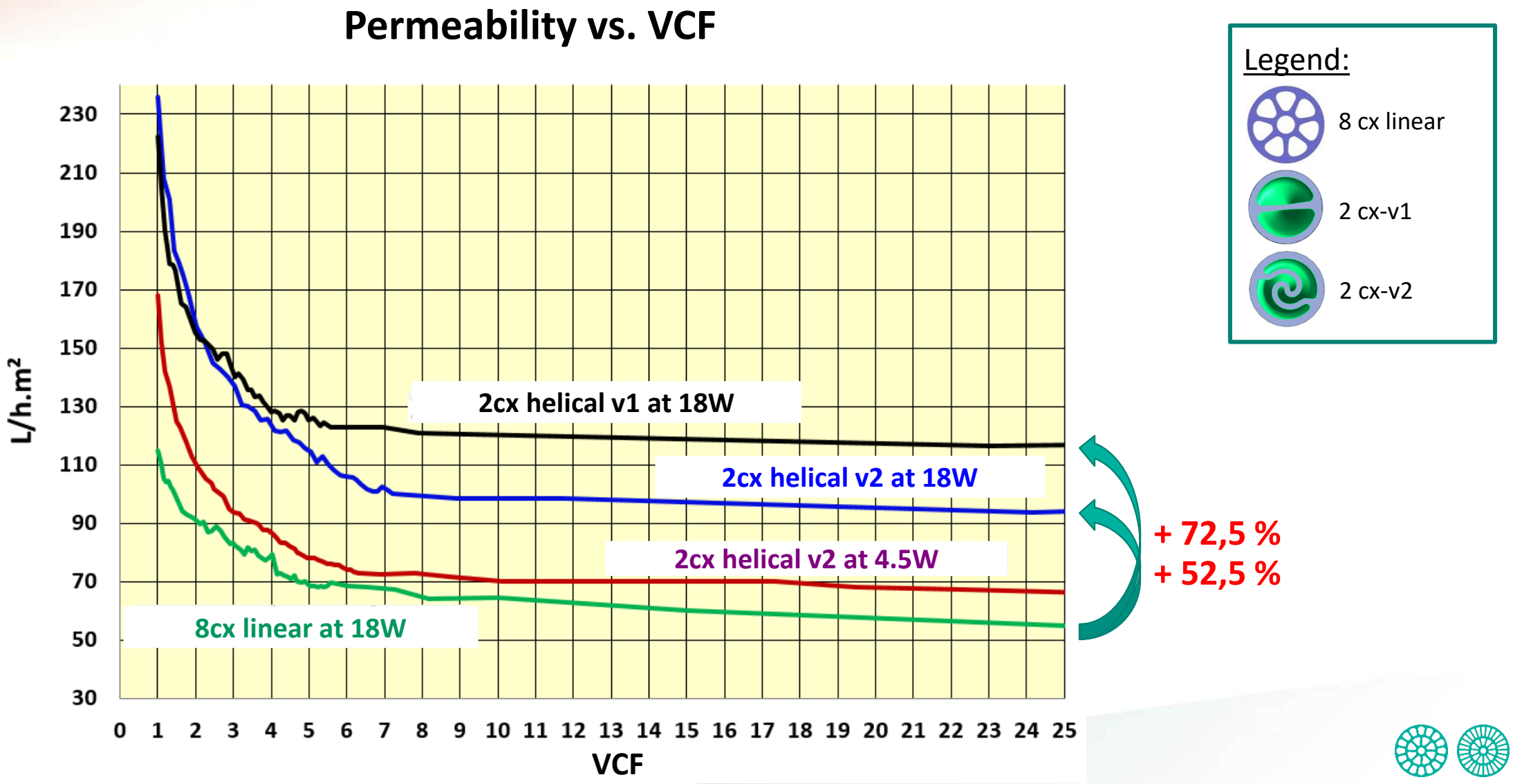
Reference velocity: **2.5m/s** (that of a membrane of 8 linear channels)

Temperature: room temperature

Absence of backflush

Repeatability: validated by multiple tests

Results on real liquid with the new shapes



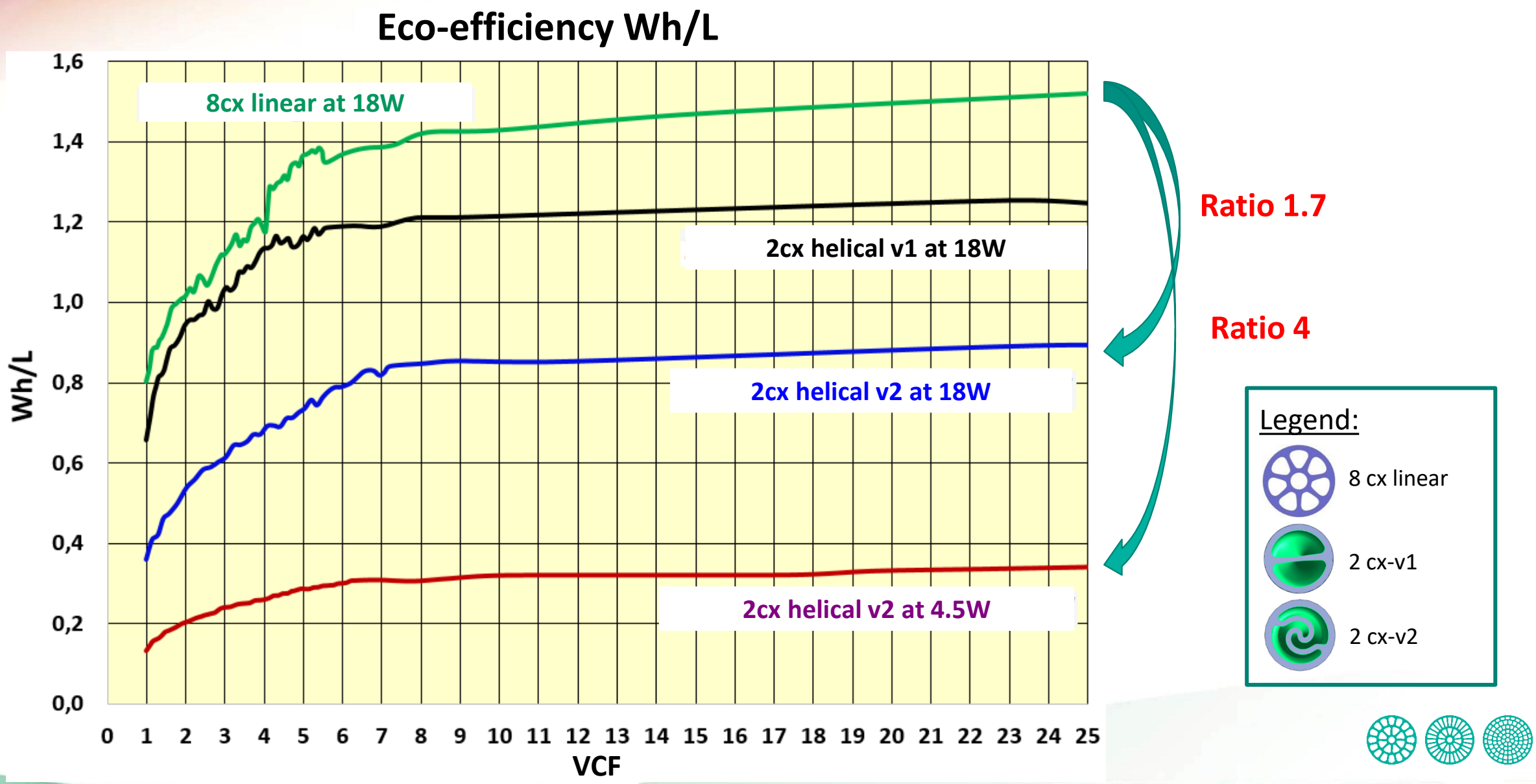
Results on real liquid with the new shapes

Eco-efficiency measured in Wh/L:

It was decided to test and assess the energy efficiency of the new membranes by comparing them to 8 linear channel membranes, in terms of electricity consumption of the recirculation pump (Wh) needed to produce 1 liter (L) of permeate.

The energy efficiency (or the average energy consumption to each liter of permeate) is given in Wh/L.

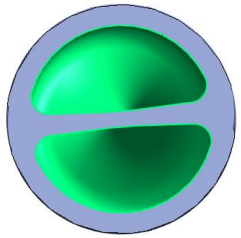
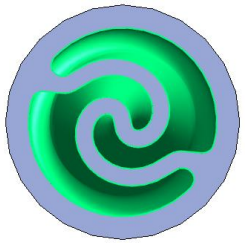
Results on real liquid with the new shapes



Results on real liquid with the new shapes

Summary (average values)	Average velocity [m/s]	Power [W]	Average permeate flux [L/h.m²]		Average energy to produce 1L of permeate [Wh/L]		Ratio of energy to produce 1L of permeate (8cx linear)
8cx linear	2,5	18	80		1,2		**1**
2cx - v1	2,1	18	138	↑ **72,5%**	1,1	↓ **8,4%**	**1,1**
2cx - v2	1,4	18	122	↑ **52,5 %**	0,7	↓ **41,6%**	**1,7**
	0,9	4,5	82	↑ **2,5%**	0,3	↓ **75%**	**4**

Comparison of 2 channel v1 vs. 2 channel v2

	 2 channel helical version 1 (**2cx-v1**)	 2 channel helical version 2 (**2cx-v2**)
Hydraulic diameter (mm)	11,5	6,5
Surface (m^2)	0,1	0,2
Properties	Wide range of rheology	Same filtration surface of an 8 linear channel

Conclusion

Tubular ceramic membrane with 2 helical channels, version 2:

+ 50% of permeate flowrate at the same power consumption*

OR

4 times less power consumption at the same permeate flowrate*

(*) compared to a tubular ceramic membrane with linear channels, same hydraulic diameter and filtration surface.

⇨ **Eco-efficiency objective achieved by ceramic tubular membranes with twisted channels**