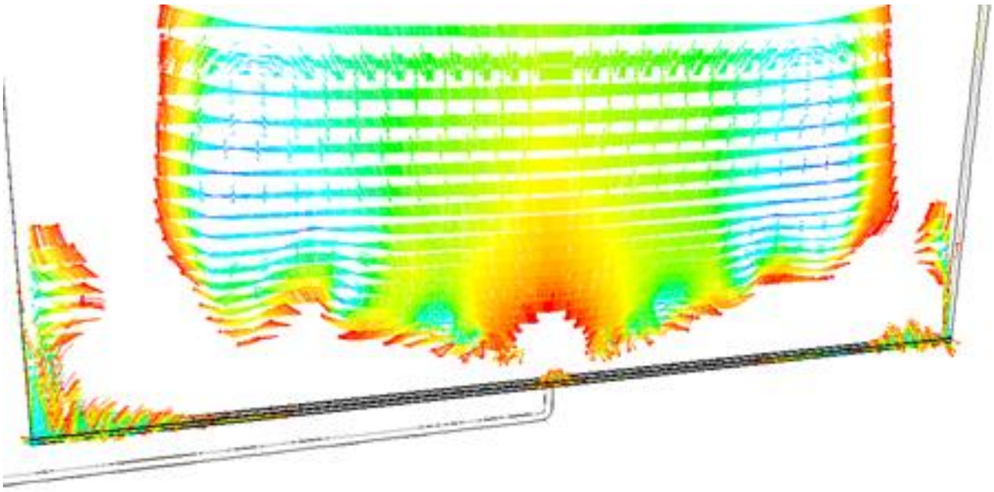
Report on geometrical variants of glazing and fluid composition concepts for the FFG façade



This document represents a report in WP2:
Fluid simulation for building envelope and interior

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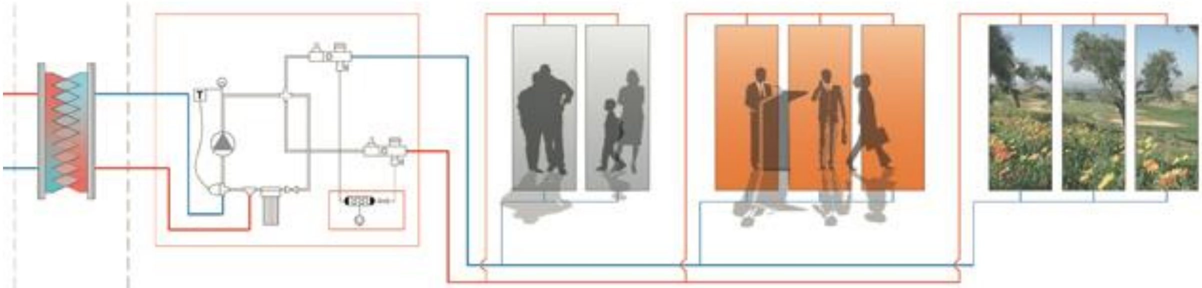
The size and the basic design of the triple fluid flow glazing (FFG) façade unit is defined including all glazing layers (multilayered, tempered, coated, etc.) as well as the two fluid chambers between.

A crucial design requirement for the FFG element is the uniformity of the fluid flow inside the fluid chamber. On the one side it has a huge influence on the thermal and energetic properties of the FFG. On the other side it determines the pressure drop in the FFG element and thus the required electrical pump power. Requirements for the maximal pressure drop of the FFG element were defined. Furthermore, a special distribution mechanism was developed which provides an almost homogenous flow and reduces the pressure drop in the fluid chamber. First development steps towards effective fluid distribution channel system inside a single FFG unit and in a big scale facade were done.



Content

1 Content of deliverable

Report on geometrical variants of glazing and fluid composition concepts for the FFG façade

This deliverable presents the results of the current state of FFG design development and geometrical structure optimization. An initial design of a new FFG element for big scale FFG facades was elaborated including definition of geometrical size, shape and material composition. This is a starting point for the development of an optimal configuration of FFG with regard to energetic performance and producibility.

One main goal of this work package is to improve thermal capacity and reduce thermal stress and hydrostatic pressure of FFG. An important prerequisite for this is to have a homogeneous fluid flow distribution in the fluid chamber. By means of CFD simulation the exact fluid behavior and pressure drop within a real scale FFG element were calculated and visualized, and a novel fluid distribution mechanism within the fluid chamber was developed. First geometrical and physical simulation models of the FFG were elaborated and various geometrical variants were analyzed.

The FFG design, geometrical and functional optimization done in this work package have to be strictly aligned to architectonic and aesthetics requirements as well as to the material and manufacturing requirements which are subject of WP 4,5 and 6.

2 Results and Discussion

2.1 Design and size of FFG façade element

The size of the FFG façade element was defined to be 3x1.3 m (height x width). Based on the expertise of the partners B&G and Architectonika the consortium agreed on this size for the reason that this is the store height in contemporary office buildings.

Also, the basic preliminary design of the façade element was defined (Figure 1) including three glazing layers and two fluid chambers between.

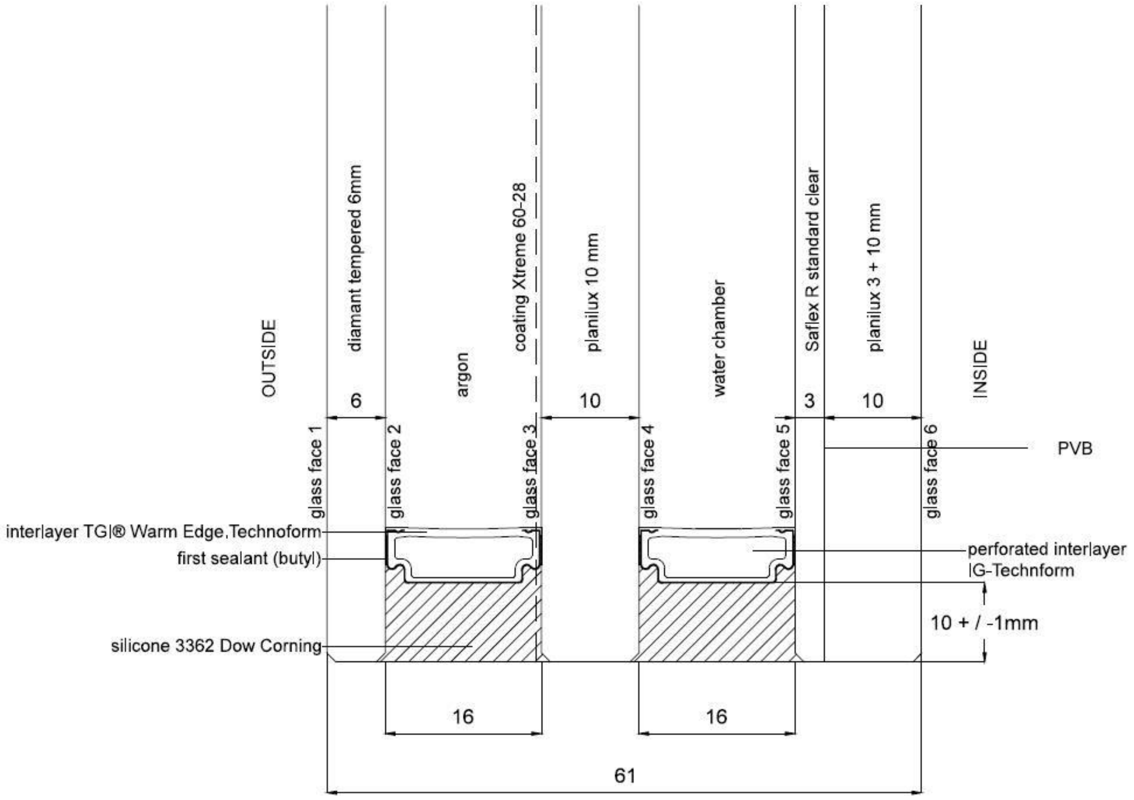


Figure 1: Definition of glazing

This glazing composition should be appropriate for climatic regions similar to Mid-Europe. In a later stage of this WP, the choice of glass and coating types has to be adapted to the specific requirements of other climates (very cold or very hot, s. Appendix WP 3). The mock-up and demonstrator development in WP 4, 5 and 6 should also provide specific stiffness, optical and production requirements that may cause further changes in this initial design and size of the FFG element.

2.2 Pressure requirements

A key issue in this project is to achieve nZEB performance with the new FFG façade, thus special attention has to be paid to the energy power necessary to operate the pumps that drive the fluid through the whole FFG façade. Thus, the pressure drop of the FFG elements and the supply pipes have to be constrained to the extent that the balance between produced and consumed energy is positive. UPM estimated a critical value of 1 W electrical power per 1 m² FFG and optimal flow rate of 1 – 2 l/min per m². This corresponds to pressure limit of 300 mbar per FFG element with ca. 4 m² area and max. flow rate of 8 l/min. Therefore, the design development in this WP has to ensure, that the total pressure drop of the FFG elements and the fluid supply piping system of the whole facade is less than this critical value.

2.3 Fluid flow requirements

The basic function of the FFG is that a chosen fluid flowing through the fluid chamber in the FFG absorbs the solar IR-radiation passing through the glazing. For the following reasons this concept will only work efficiently if the fluid flow in the water chamber is controlled, homogenous and almost laminar:

1. Regions with different velocities in the chamber result in inhomogeneous energy gain by the fluid and additional temperature gradients in the fluid and the glazing, which lead to additional stress in the glazing and accelerate further the inhomogeneity of the flow.
2. Recirculation zones cause that the energy cannot be transported through the chamber in these regions, the temperature gradients increase even more and prevent an optimal mass and energy flow through the FFG.
3. In case of fluid contamination, the risk of disruptive deposits in recirculation zones increases dramatically.
4. Turbulent zones increase the pressure drop of the fluid chamber.

2.4 Fluid chamber requirements

As to be seen on Figure 1 the fluid chamber of the FFG is the space formed between two glass planes separated by a spacer (“interlayer Technoform”). The design of the spacer counts to two basic functions: 1) Holding the two glass planes and providing stiffness to the FFG element. 2) Supplying the fluid to the FFG and distributing it homogeneously and with low pressure drop to the chamber. For future large-scale applications of FFG the consortium agreed to integrate the water supply mechanism in the frame (spacer) of the new FFG element instead of mounting external pipes to the façade as in earlier demonstration sites.

The brightness of the fluid chamber / spacer is very important since it determines the fluid volume and consequently the fluid flow velocities, the pressure drop and the overall weight of every FFG element. Currently it is defined to be 16 mm. In WP 4 and 5 must be elaborated if these dimensions can be realized with regard to FFG stiffness, gluing technology and leakage prevention.

2.5 Spacer design study

Figure 2 shows the first generation of perforated spacer used in double glazing fluid flow elements and tested on a lab scale by UPM. This spacer was incorporated in the initial design of the new FFG unit on Figure 1.

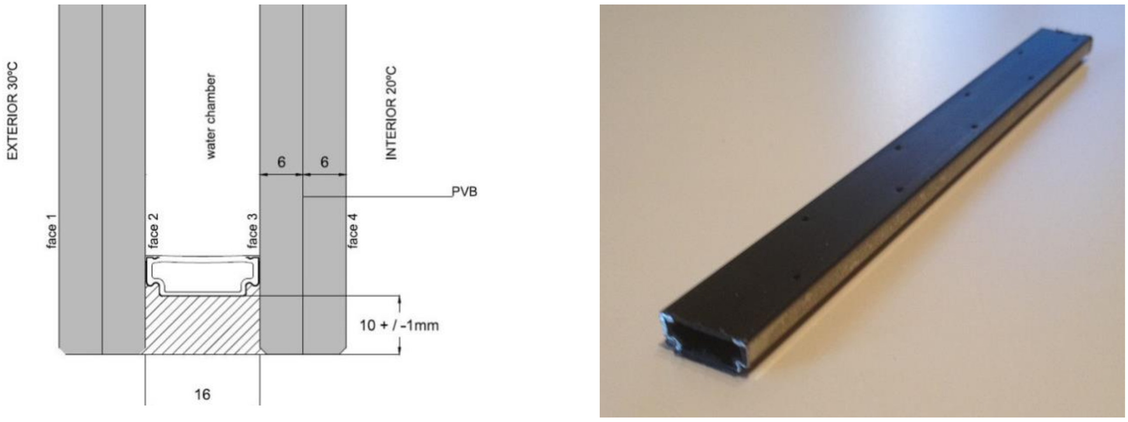


Figure 2: Currently used spacer on laboratory scale

It was already observed in the lab that this kind of spacer does not provide a homogenous flow in the chamber. In this WP HTCO modelled the new large scale FFG element using the perforated spacer geometry (Figure 3) and visualized the actual flow behavior in the chamber via CFD simulations (Figure 4). The simulation results verify the lab results and show that the pressure drop is much higher than required.

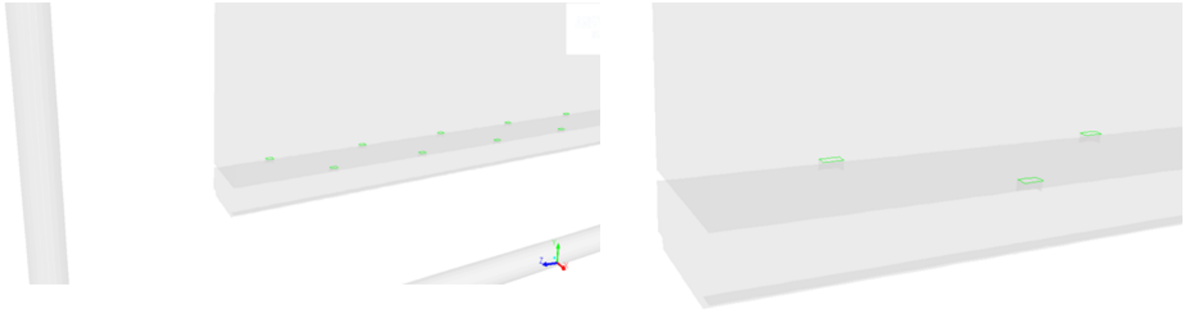


Figure 3: CFD-simulation model: perforated spacer geometry in the initial FFG design

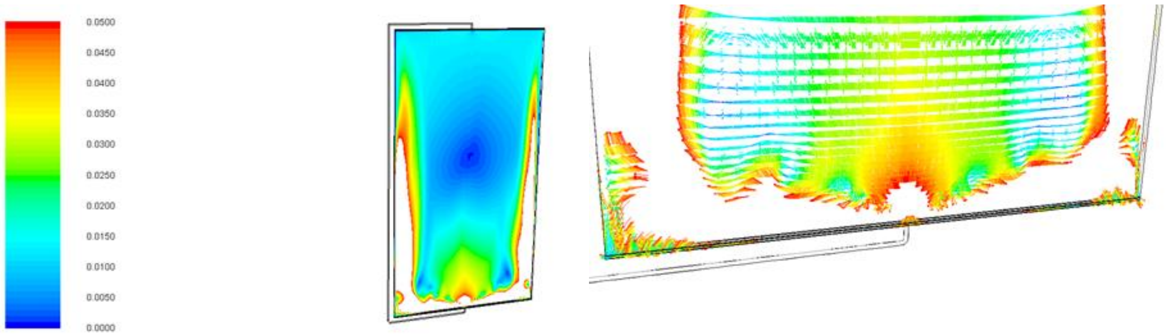


Figure 4: CFD-Simulation results: velocity distribution [m/s] in the fluid chamber with perforated spacer

2.6 Spacer design optimization

A geometry study with different kinds of spacer perforation showed similar results. Thus, this kind of spacer geometry is not suitable for the new FFG element and a more advanced design has to be developed that satisfies the requirements from 2.3.

Based on the experience of HTCO in fluid dynamics a new innovative spacer concept with integrated fluid supply pipe and labyrinth mechanism was developed (Figure 5 and Figure 6). The spacer and the inner fluid pipe are bigger than the initial one in order to reduce the pressure drop. The labyrinth principle transforms the high linear momentum in the pipe to a slow momentum in vertical direction. The fluid is distributed in the chamber through a thin slit along the whole length of the spacer instead through perforated holes (blue surface on Figure 5).

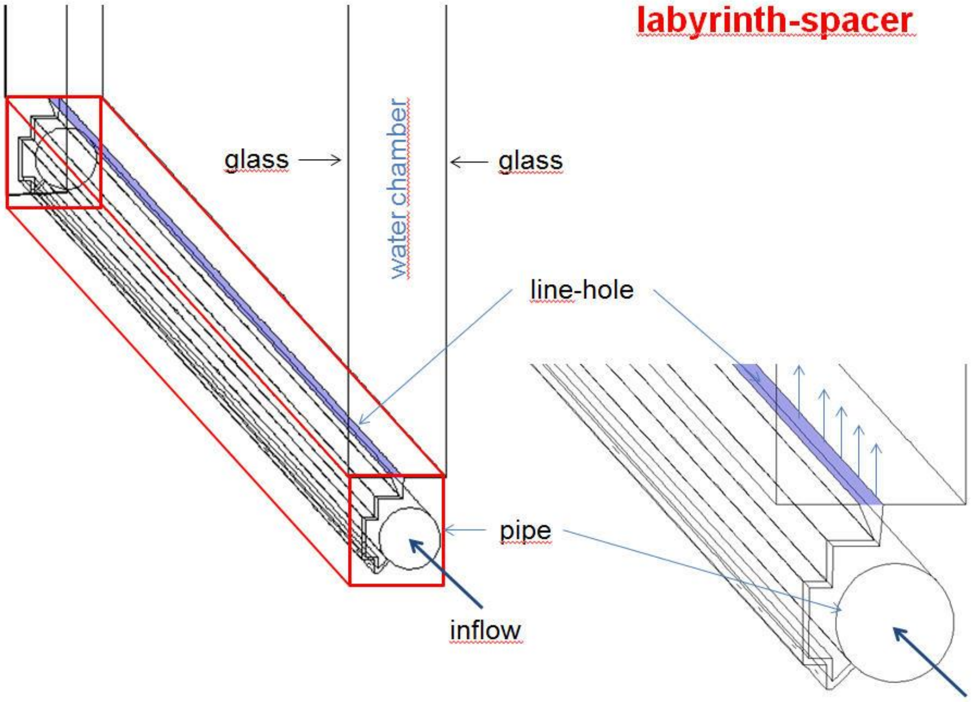


Figure 5: Labyrinth based spacer design

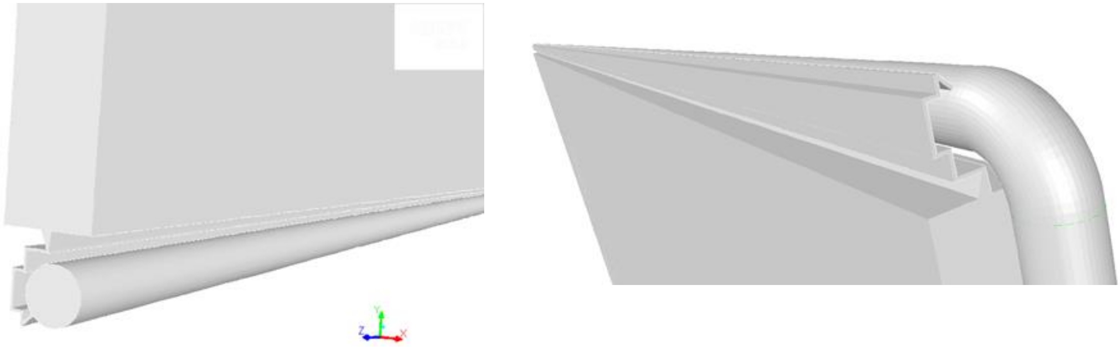


Figure 6: CFD-simulation model: labyrinth spacer geometry of the inflow (left) and the outflow (right) spacer with bend and downward pipe

A geometry study with different kinds of labyrinths was performed. The best spacer design so far shows already very good results (Figure 7and Figure 8). The flow in the chamber is almost homogenous, there are only very small regions with velocities higher than 2 cm/s near to the inlet and outlet of the chamber. Nevertheless these velocities are almost 10-times lower than the maximal velocities in the perforated spacer from above. Figure 8 shows with regard to the horizontal velocity distribution that there are horizontal components only in the area of the inflow and outflow pipes, the fluid is flowing almost uniformly upwards through the chamber.

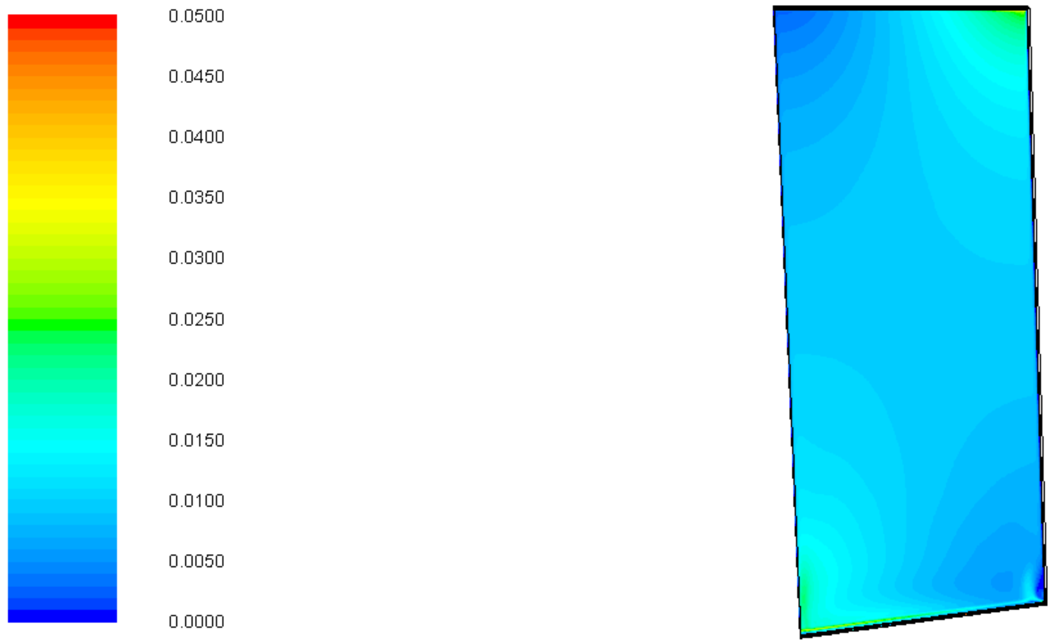


Figure 7: CFD-simulation results: velocity distribution [m/s] in the fluid chamber with labyrinth

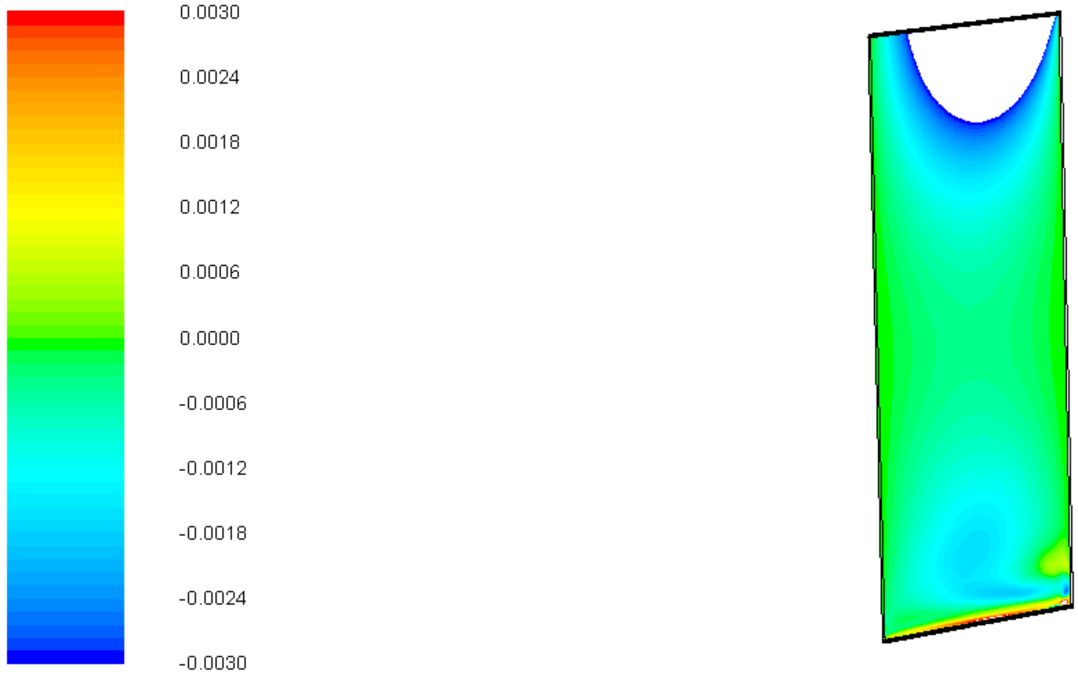


Figure 8: CFD-simulation results: horizontal velocity components [m/s] in the fluid chamber with labyrinth spacer

The labyrinth spacer has also another big advantage compared to the perforated spacer. It is designed to be produced by extrusion and no additional production steps (like perforating) are needed, which is very important with regard to low-cost industrial production of the FFG-components.

After the labyrinth spacer design was communicated to WP 4 and 5 the partners found that the very narrow structures used may lead to production difficulties. For this reason, a similar design with spiral labyrinth spacer instead was designed (Figure 9). The velocity distribution in the first few analyzed geometries is a little bit less homogenous than before, but HTCO does further optimization work on that topic.

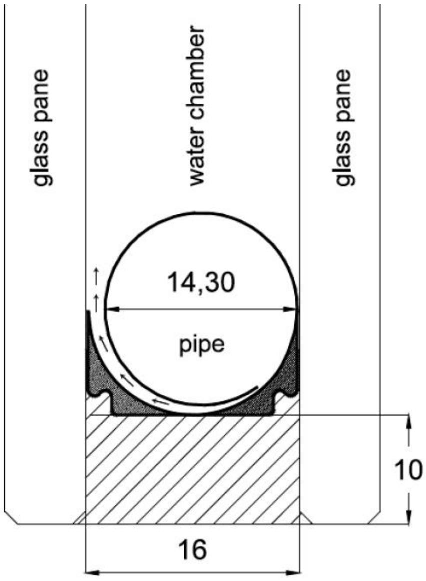


Figure 9: Spiral labyrinth spacer design

2.7 Piping concepts

Not only was the spacer design studied in WP2 but also possible perfusion mechanisms in the fluid chamber. Following mechanisms for the inflow and outflow directions were discussed (Figure 10).

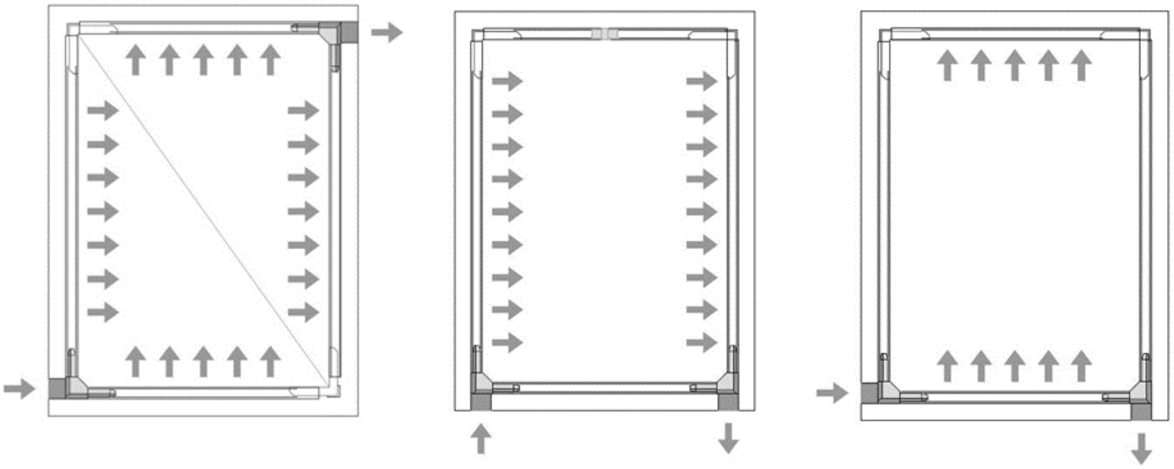


Figure 10: Perfusion mechanisms through the fluid chamber: diagonal (left), horizontal (middle), vertical (right)

Theoretical estimations (UPM) and numerical CFD-analysis (HTCO) revealed that the best perfusion direction in the chamber is vertical. The fluid flows upward through the FFG unit. The reason for this is that in operation there will be temperature gradients in the fluid which will induce natural convection inside the chamber driving the fluid upward. The CFD analysis of the fluid flow in stagnation and dynamic operation showed that the induced velocities from convection are of the same order as the velocities induced by the pumping. Thus, if the perfusion direction is horizontal or diagonal, the fluid flow will be disturbed by the superposed natural convection leading to inhomogeneous flow distribution in the chamber.

Additionally, after being collected in the upper outflow spacer the fluid must be transferred along a 90° bend and vertical side spacer downwards (s. Figure 6, right) so that the inlet and the outlet are on the same side of the FFG unit. Experimental lab experience at UPM shows that positioning the fluid inlet and outlet on the same side of the FFG minimizes the risk of air leakage and allows easier mounting to the supply piping system. However, the downward flow through a pipe of 3 m length and with high velocity (ca. 2.5 m/s at flow rate of 8 l/min, s. Figure 11) leads to high pressure drop in this pipe.

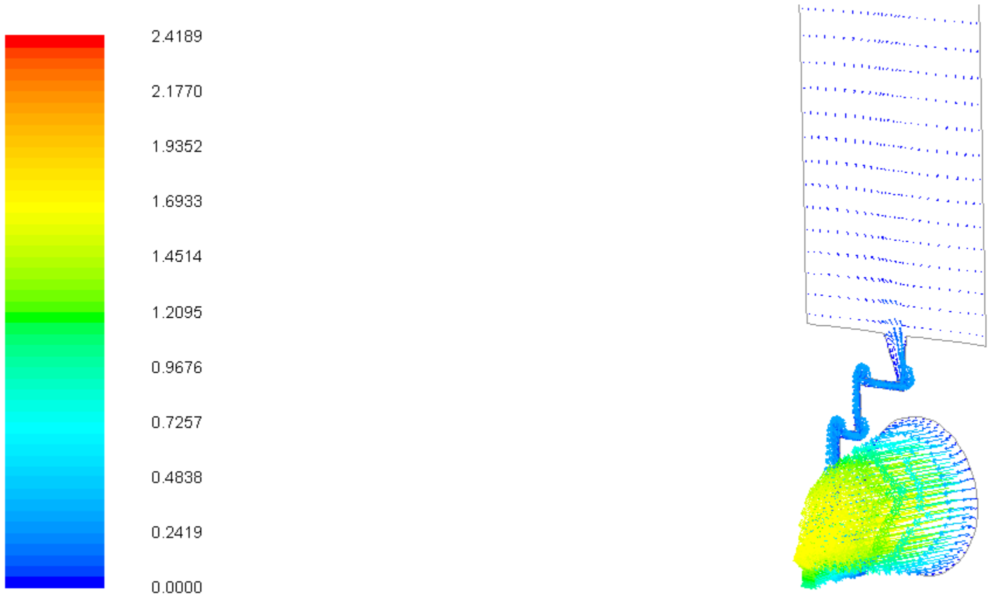


Figure 11: CFD-simulation results: velocity [m/s] in the supply pipe of the inflow labyrinth spacer

Figure 12: CFD-simulation results: pressure distribution [Pa] in the upper part of the FFG element and the outflow spacer

The CFD quantitative results show that the upper outflow spacer and the downward pipe have the highest pressure drop in the FFG element and the fluid chamber itself causes fast no pressure drop (Figure 12 and Table 1). Thus, special emphasis has to be taken regarding the design of the spacer and the integrated pipes.

Table 1: Pressure drop FFG element

	Mass flow [kg/s]	ΔP_{total} [Pa]	$\Delta P_{inflow\ spacer}$ [Pa]	$\Delta P_{chamber}$ [Pa]	$\Delta P_{outflow\ spacer}$ [Pa]	ΔP_{bend} [Pa]	$\Delta P_{downflow\ pipe}$ [Pa]
Labyrinth spacer, 3.9 m²	0,133	9200	485	4	4229	308	4174

The current configuration of the labyrinth spacer with inner pipe results in total pressure drop of 92 mbar for one FFG unit with 3.9 m² area at 8 l/min. This is less than the critical value of 300 mbar as defined in 2.2.

However, a complete big scale FFG façade consists of several FFG elements. Therefore the additional pressure drop of the fluid distribution piping system for the whole façade must be also considered in the calculation of the total pressure drop of the system. First concepts of the fluid distribution piping system and its connections of the separate FFG units were proposed (ETEM, Figure 13) which have to be further optimized with concern to pressure drop.

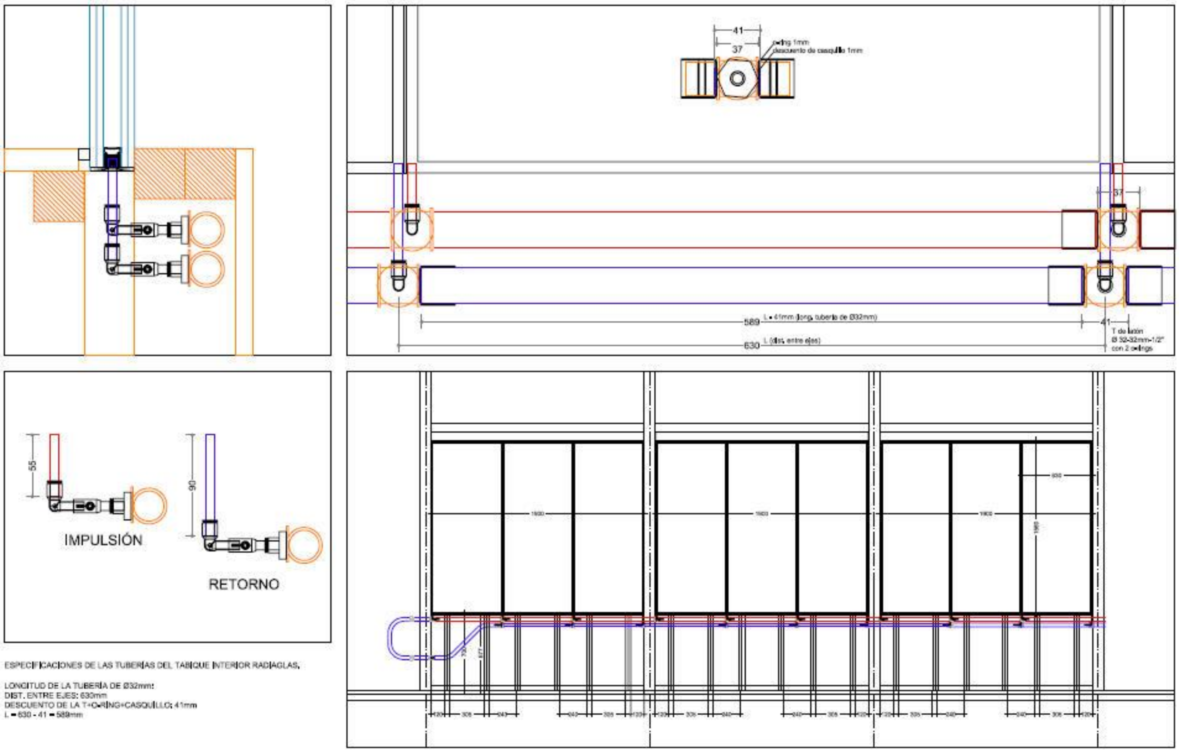


Figure 13: Piping concept for a whole FFG façade

3 Degree of Progress

There is no deviation from the work plan.

4 Dissemination

These results were not published up to now. To partners involved in WP 2 some of the results were already presented during the weekly telco meetings.