Summary on patent application relative to a two phase flow impeller with Phase Velocity Control (PVC design)

State of the art: radial and axial impellers do not permit to increase significantly the pressure of a two phase flow mixture. In the first case, the liquid phase is expelled at a very high velocity, relatively to the gas phase, towards the exit while, in the second case, the liquid phase is transported at a lower velocity than the gas phase one. In both cases, the large phase velocity difference generates high interfacial losses but also high friction, diffusion and entrance losses.

Forty years ago, a **helico axial impeller** has been developed showing a greater facility in compressing a two phase mixture. This impeller, developed at IFP (called Poseidon), is characterized by very long blades with a very large radius of curvature. This design provides low acceleration in three orthogonal directions (longitudinal, transversal and radial) permitting mixing of the two phase flow when the GLVR is small (Gas – Liquid Volume Ratio). Above that range, the separation is unavoidable generating large interfacial losses. Like for an axial impeller, the liquid velocity is smaller than the gas velocity. Also, the blade design provides large friction losses and a small difference in blade angles (inlet to outlet), resulting in medium - low efficiency and pressure coefficient in single phase flow. Different types of two phase losses are generated due to the discrepancy in phase velocity.

New impeller design (PVC): fundamentally different to the Poseidon one. There is no attempt with the PVC design to improve the mixing of the two phases in order to facilitate their transport (case for Poseidon). Instead, **the PVC design promotes the separation of the two phases** (except for very low GLVR) in order to control the velocity of each phase relatively to the other. This control is permitted by using the component of the radial force acting on the impeller outside surface (cover). **By controlling the slope of the cover**, therefore, the driving forces applied on the two phases with a different density, **it is possible to control locally the sliding factor (Vl-Vg)/Vg** and set it as close as possible to zero reducing equally interfacial losses to zero.

This mechanism may be easily verified in **the case of two phases** (liquid and gas with different density) **flowing in a long straight tube** and with a radial force acting on that tube: case of a fixed horizontal tube or a channel rotating parallel to the rotation axis. When the radial force is exactly perpendicular to the tube (channel), there is no effect to the flow and the slip factor is negative (Vl<Vg). However, when the tube (channel) is inclined, the component of the radial force (gravity for the tube and centrifugal force for the channel) tends to decelerate the liquid phase (tube oriented upward) or accelerate it (tube oriented downward) permitting, in this second case, the liquid velocity to reach or even exceed the

gas velocity. The mechanism for accelerating the liquid phase in a 3D impeller channel is more complex acknowledging the different centrifugal and centripetal forces acting on the two phase flow. Also, the **Coriolis force** is not the same at the wall and the core of the channel due to the velocity gradient in each phase (from the wall laminar to the core turbulent layer).

With the PVC design it is possible to relax the minimum acceleration criteria (contrary to a Poseidon impeller) and let the phases to separate at an earlier stage than with a Poseidon impeller. As a consequence, the blades may be selected shorter, the blade inlet angle greater and the blade curvature radius shorter. It results, in single phase flow, a greater efficiency and a greater pressure coefficient. It results in two phase flow, smaller interfacial losses but also smaller friction, diffusion and diffuser entrance losses, i.e. a considerably greater two phase flow efficacy. As an overall, the two phase performance (efficiency and pressure coefficient) is considerably increased. Note: TP Efficiency = SP Efficiency * TP Efficacy. Similar relation for the pressure coefficient.

Main benefits of the PVC impeller relatively to the Poseidon impeller – Domains of application – ***Significant benefits***: from GLVR = 1 to 10 (The "critical GLVR zone") – ***Important benefits***: low gas density or high liquid viscosity – ***Very important benefits***: combination of the above elements, Critical GLVR zone AND low gas density OR Critical GLVR zone AND high liquid viscosity OR low gas density AND high liquid viscosity OR combination of the above three elements.

Patent application: The patent has been filed on July 19th 2017 in France. Extension abroad will have to be made before July 19th 2018 (Expiration of priority date).

The preliminary search report has been received on March 26th 2017. The examiner considers that the invention is new, inventive and susceptible of industrial applications.

Proprietary rights may be transferred to any company interested by this patent.