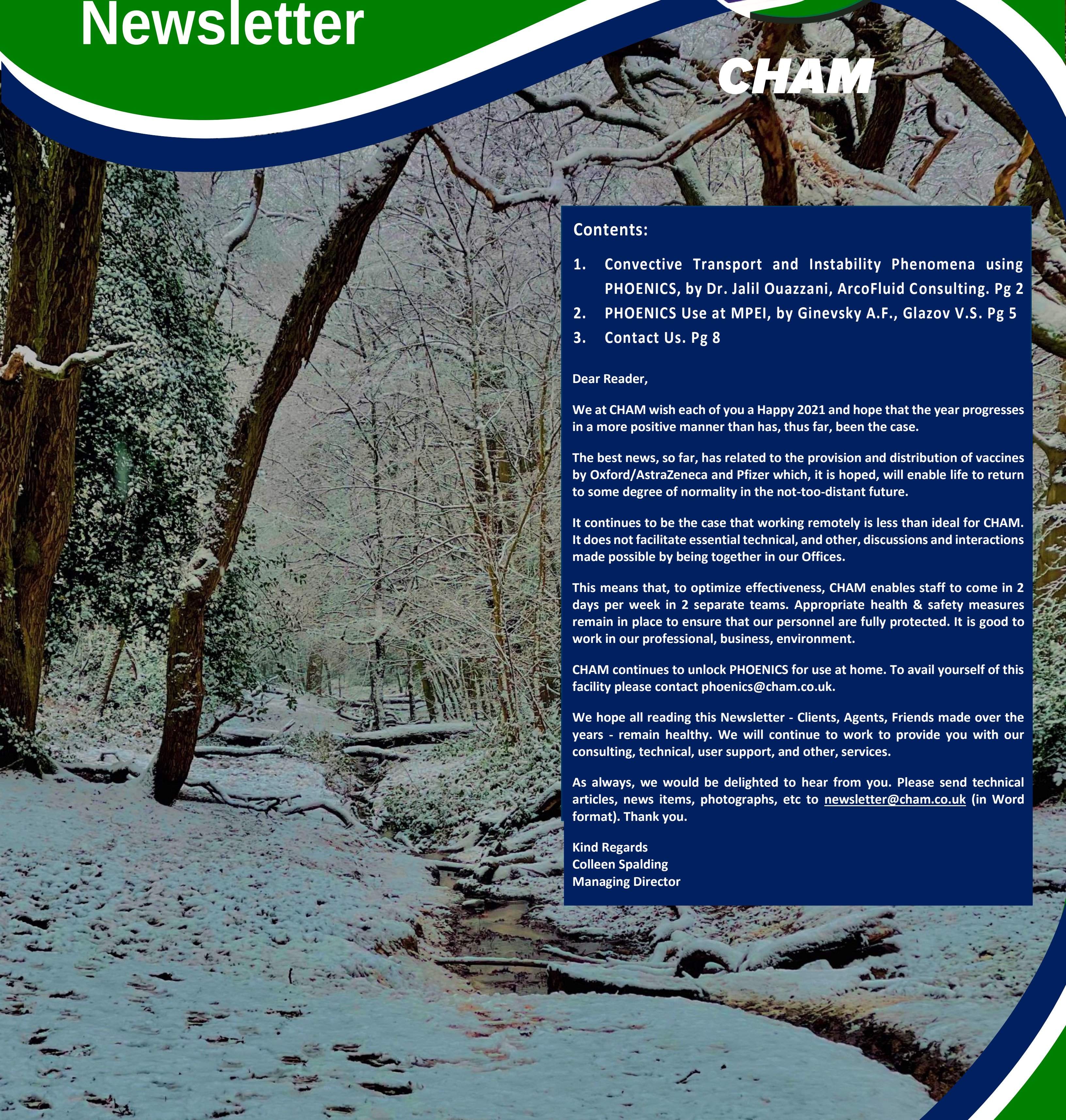
PHOENICS Newsletter

CHAM



Contents:

Dear Reader,

We at CHAM wish each of you a Happy 2021 and hope that the year progresses in a more positive manner than has, thus far, been the case.

The best news, so far, has related to the provision and distribution of vaccines by Oxford/AstraZeneca and Pfizer which, it is hoped, will enable life to return to some degree of normality in the not-too-distant future.

It continues to be the case that working remotely is less than ideal for CHAM. It does not facilitate essential technical, and other, discussions and interactions made possible by being together in our Offices.

This means that, to optimize effectiveness, CHAM enables staff to come in 2 days per week in 2 separate teams. Appropriate health & safety measures remain in place to ensure that our personnel are fully protected. It is good to work in our professional, business, environment.

CHAM continues to unlock PHOENICS for use at home. To avail yourself of this facility please contact phoenics@cham.co.uk.

We hope all reading this Newsletter - Clients, Agents, Friends made over the years - remain healthy. We will continue to work to provide you with our consulting, technical, user support, and other, services.

As always, we would be delighted to hear from you. Please send technical articles, news items, photographs, etc to newsletter@cham.co.uk (in Word format). Thank you.

Kind Regards
Colleen Spalding
Managing Director

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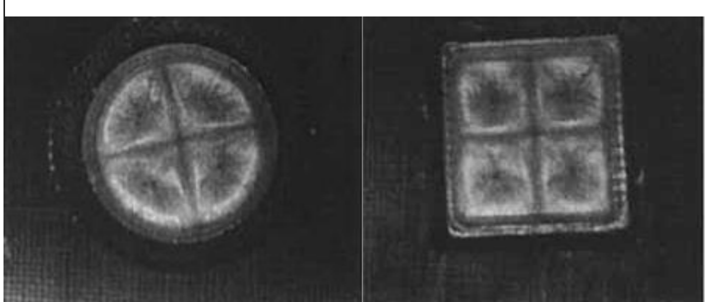
Winter 2020

The onset of motion in heated fluid layers with a free upper-surface has eluded complete understanding ever since Benard's investigation of these flows established thermal convection as a paradigm for pattern formation in nonequilibrium systems. Rayleigh's analysis of this problem assumed that buoyancy effects, which are always present in layers heated from below, caused convection, but the threshold that Rayleigh predicted did not agree with Benard's observations. Forty years elapsed before it was recognized that the instability observed in Benard's studies was not caused by buoyancy but by surface tension gradients, as characterized by the Marangoni number Ma. In order to investigate the capabilities of PHOENICS to treat the Onset of Surface-Tension-Driven Benard Convection, we have considered the experiments from Koshmieder & Prahl detailed in the following papers.

In collaboration with University of Marseille, France, we have set in PHOENICS 2019, a 3D model which account for the coupled Rayleigh-Benard-Marangoni (RBM) problem, first using only one layer with adequate boundary conditions and then using two layers.

The one layer case

First, we consider the one-layer case in a square cavity and then in a circular cavity. The upper surface has the boundary condition on velocity to account for thermocapillary-driven convection, and a heat flux proportional to $\Delta T/d$ (where d is height of liquid and ΔT is the temperature gradient between hot and cold). The following two cases were taken:



Ma = 78; Ra=38; Γ=6.79	Ma = 78; Ra=38; Γ=6.36

Having a flat free surface, we used the following parameters: Ma=92 (Marangoni number); Ra=30 (Rayleigh number) and aspect ratio Γ (width/height) = 8.2.

Results for the circular case:

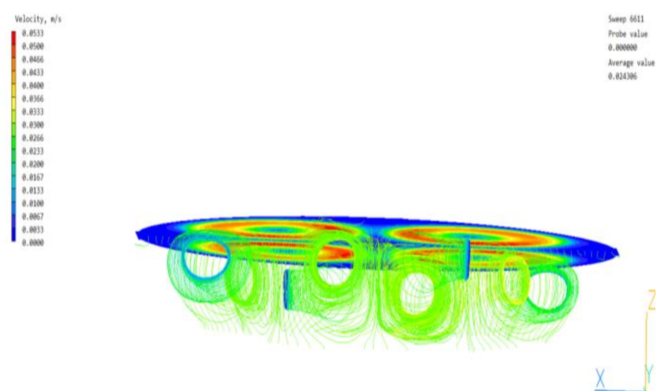


Figure 1: Streamlines (upper surface represent velocity.)

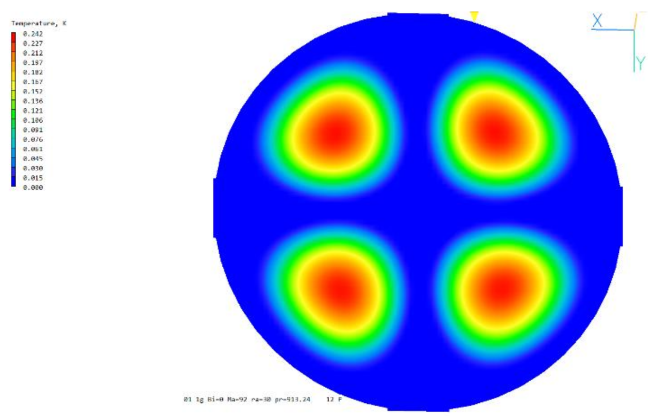
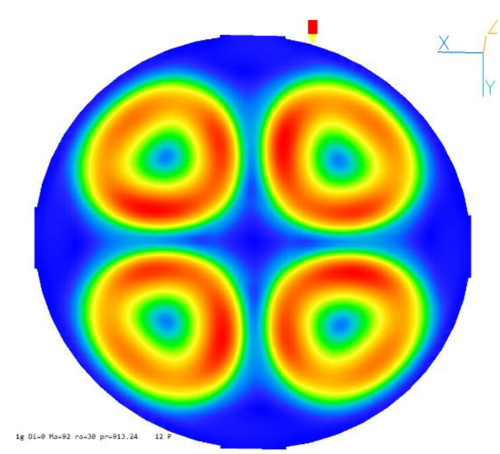


Figure 2: Temperature contours at the upper surface



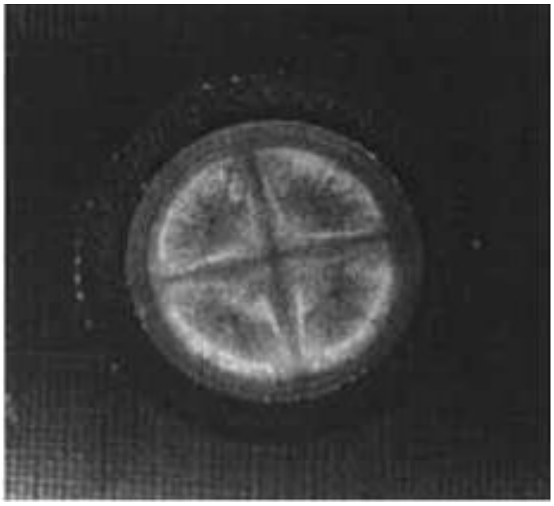


Figure 3: velocity contours at the upper surface (view from a different angle). Below, the experimental results.

Results for the square case:

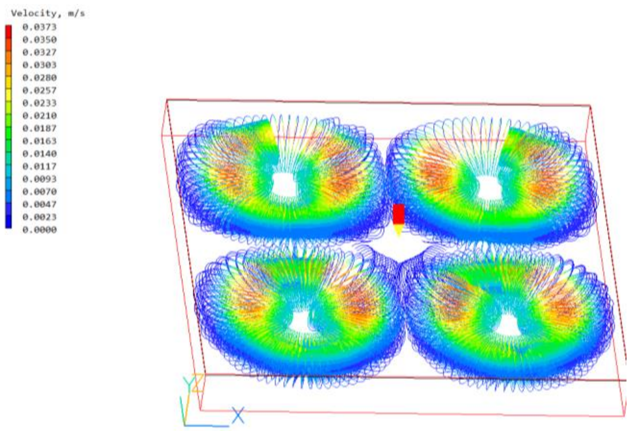


Figure 4: Streamlines and velocity contours at the upper surface.

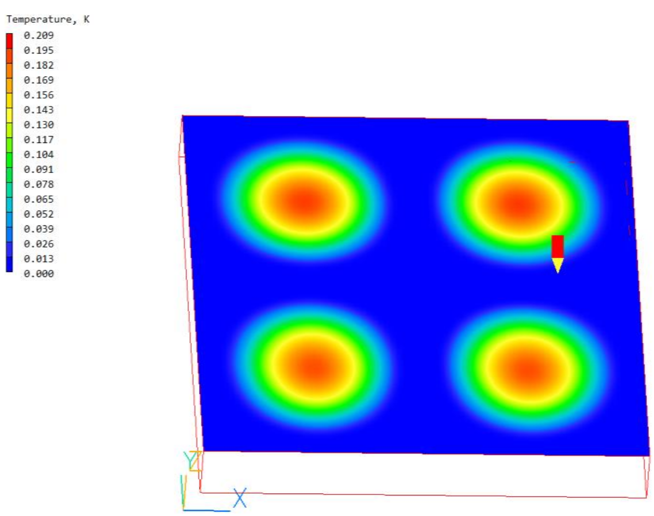


Figure 5: Temperature contours at the upper surface (view from a different angle).

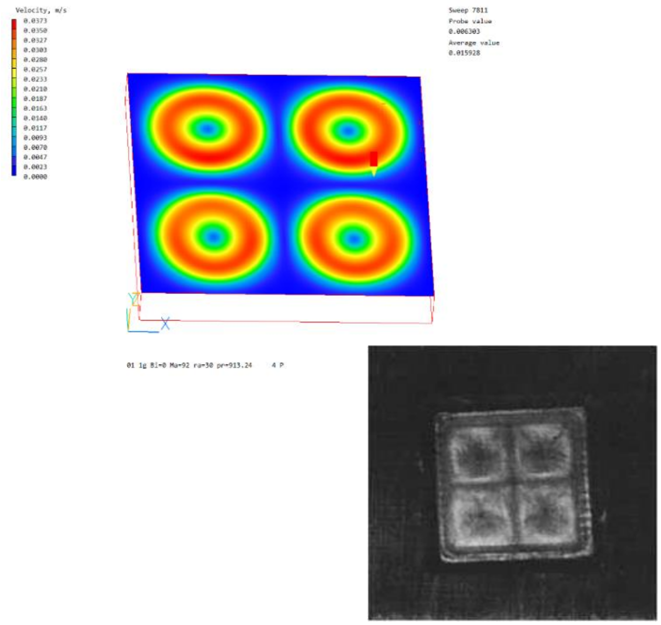


Figure 6: velocity contours at the upper surface (view from a different angle). In the right, the experimental results.

The two layers case

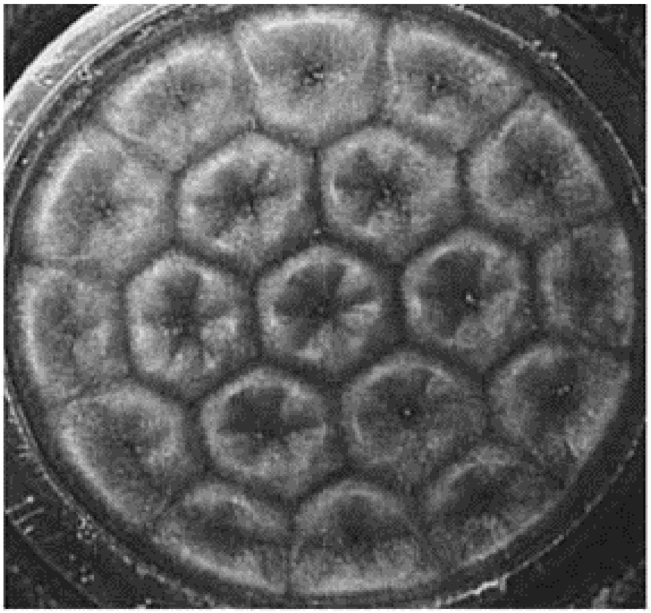
This consists of two layers of fluid (Air – Silicon oil), separated by a frictionless plate, where proper boundary conditions of continuity and surface tension are imposed. For the air we consider a very low viscosity in order to create a disturbance at the liquid surface. In the experiments of Koschmieder at al, the convection in the thin layer of air brings disturbances which in turn activate thermo-capillary convection.

We have chosen the case of the cylindrical cavity with an aspect ratio Γ = 18. 3 (Γ = D/d which is (diameter of liquid layer)/ (height of liquid layer) where D= 23.8 mm and d=1.3 mm. The height of the air layer is 0.5mm. At the top of the Air layer, we consider a plate with dimensionless temperature equal to zero. At the bottom of the liquid layer, we consider a plate with dimensionless temperature equal to one.

The sidewalls are chosen to be adiabatic. The chosen fluid is silicon oil with properties given in the Koschmieder et al paper. We used the equations in dimensionless form.

Case considered:

Ma= 88; Ra= 27; Pr =913.24; ΔT=14.35°C (Pr the Prandtl number and ΔT the difference of temperature between hot and cold surfaces). For this case, Koschmieder et al observe the following patterns:



Using a Cartesian 3D cut-cell approach, we used PHOENICS with a mesh of 90x90x50. The mesh in X & Y could be refined to avoid disturbances from the sidewalls approximated using a cartesian mesh.

Results were obtained with Phoenics for three cases, as follows:

1. Case I ∆T=14.35°C*2= 28.70046°C Ma=166; Ray=54; Pr =913.24
2. Case II ∆T=14.35°C*1.2= 17.22018°C Ma=105.6; Ray=32.4; Pr =913.24
3. Case III ∆T=14.35°C*2= 28.70046°C Ma=166; Ray=108; Pr =913.24

Results Case 1:

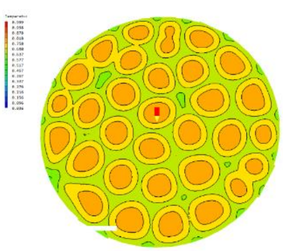


Figure 7: Temperature contours at the interface

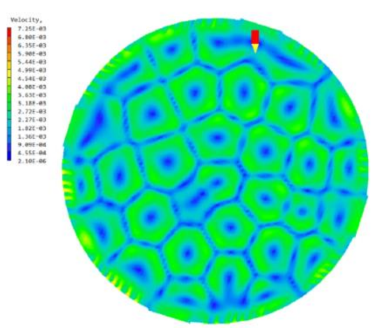


Figure 8: Velocity contours at the interface.

Results Case 2:

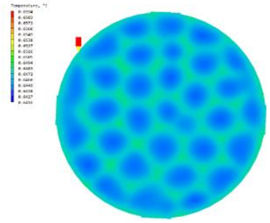


Figure 9: Temperature contours at the interface

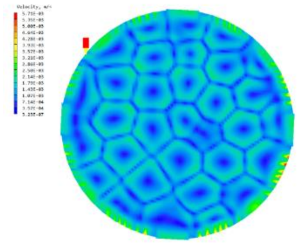


Figure 10: Velocity contours at the interface.

Results Case 3:

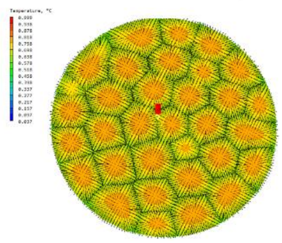


Figure 11: Temperature contours at the interface and velocity vectors

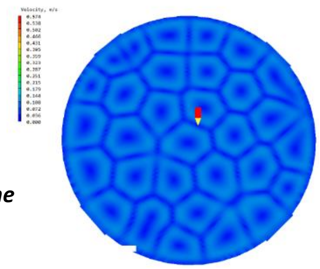


Figure 12: Velocity contours at the z=0.99 (interface is at z=1)

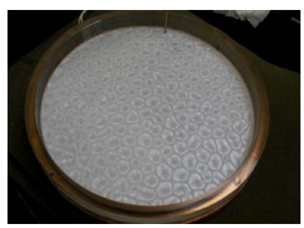


Figure 13: Photo of Rayleigh-Benard experimental set up with a free upper surface (From John Matsson, thesis).

We can see that the model with two layers as defined in PHOENICS is working very well and predicts correctly the RBM cells. A thorough study is needed to cover the experiments of Koschmieder et al, to check the effect of surface undulation. The later can be now done in PHOENICS with the VOF-THINC method.

References:

Surface-tension-driven Bénard convection in small containers

E. L. Koschmieder, S. A. Prahl

Published online by Cambridge University Press: 26 April 2006, pp. 571-583

PHOENICS in MPEI, by Ginevsky A.F., Glazov V.S. (Moscow Power Engineering Institute, National Research University)

All departments of MPEI use various numerical packages for educational and research purposes. Often, the numerical modeling is done by programs, which were developed by MPEI. However, some good famous program packages of other developers are used often too. One such package is PHOENICS, which has been used in MPEI for more than 30 years.

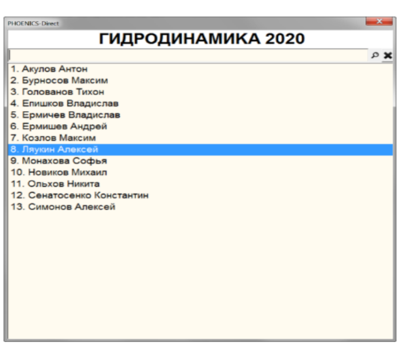
In the 20th century, PHOENICS was used in MPEI by separate persons who accessed PHOENICS from time to time. During the last 10-15 years an annual license was purchased for the entire university. PHOENICS is increasingly being used in different departments, both in the educational process and in the implementation of various non-commercial research, which are carried out by teachers together with students and graduate students.

In this article, the authors provide information on how PHOENICS is currently used in the MPEI departments where they themselves work.

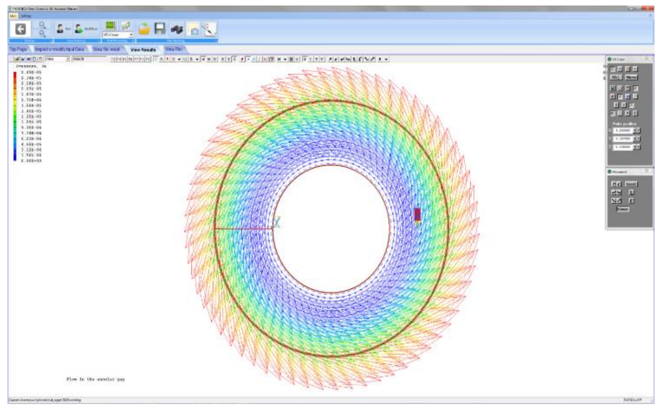
At the Department of *Low Temperatures*, PHOENICS is used in the study of the following disciplines: *Hydrodynamics*, *Numerical modeling of low-temperature processes* and *Physical foundations of new technologies*.

The course of *Hydrodynamics* is read during the 3-year Bachelors course, when students are not yet familiar with numerical modeling. They need to learn how to solve the Navier-Stokes equations and evaluate the correctness of solutions obtained. PHOENICS, or rather a part of it - PHOENICS-Direct helps students as it can be used by people who do not know about CFD at all.

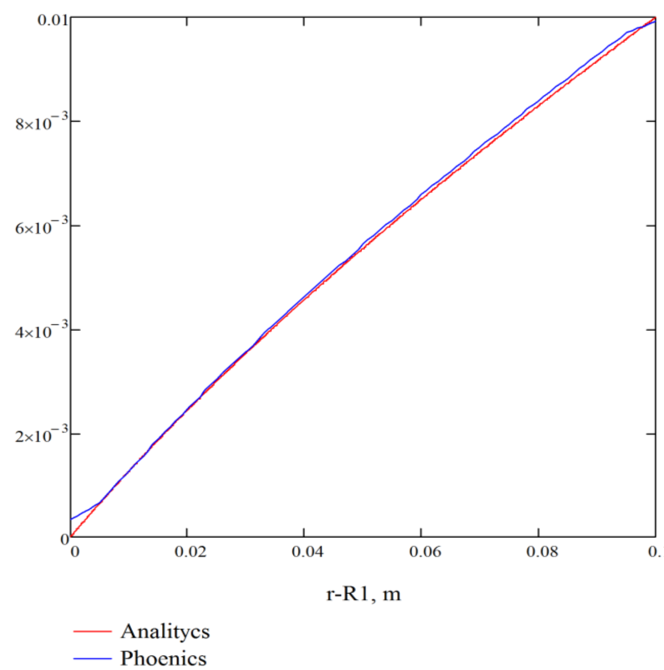
The course-work assignment for a group of students is formulated in the form of a Simulation Scenario of PHOENICS-Direct, in which each student has a personal assignment. The student chooses his last name from the list, which is presented in the figure below.



As an example, the following figure shows the computational domain for a flow in a ring and the result of the computation for the velocity field.

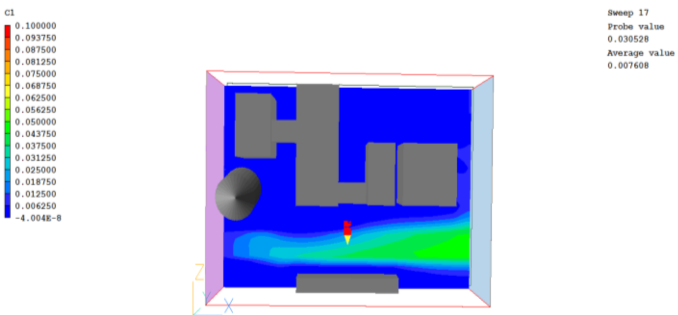


The student's task was to obtain an exact analytical solution and to compare this solution with the result of the calculation. The student coped with the task and got the following comparison picture:



This year, due to the pandemic COVID 19, starting from mid-March, all classes at MPEI in these disciplines were conducted remotely. Therefore, it was important students could complete their work on their own.

When working on the course *Numerical modeling of low-temperature processes* students study modern approaches to modeling various phenomena and processes, starting with the finite-difference approximations of hydrodynamic and transport equations on various grids and ending with the implementation of their individual tasks, which are a test of the success of the course. Individual tasks are performed using PHOENICS. The topics of individual assignments are very diverse including research of various types of heat exchangers, mixers, electronic devices, etc. For example, one of the topics is connected with the study of the spread of pollution from cars moving on roads around the building in which students are studying. The following picture shows the solution, which the student obtained for field of concentration:



The course *Physical foundation of new technologies* is a continuation of *Numerical modeling of low-temperature processes*. When studying it, students master the features of modern models of physical processes, such as turbulence models, models of two-phase flows and the features of modeling phase transitions. In addition, they learn how to create their own Simulation Scenarios of PHOENICS-Direct that include algorithms for managing calculations in Connected-Multi-Run mode.

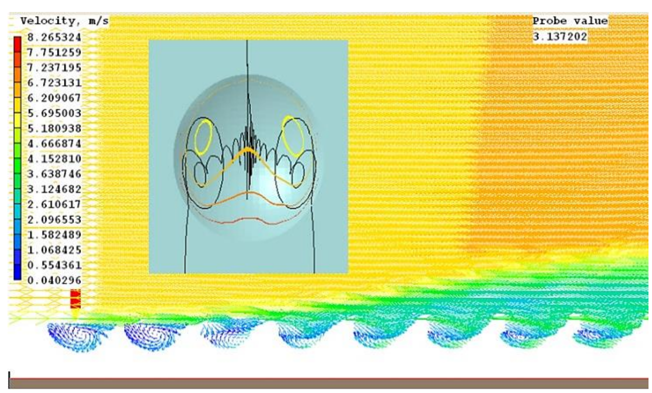
In addition to the educational process, PHOENICS is used in the research work of undergraduate and graduate students. One such research project is *Investigation of the liver cooling process for the purposes of successful transplantation*. This was carried out by the student I. Seregin. In this work, *liver* cooling is simulated using a stream of water with small ice granules that melt during movement. Such cooling systems are still unknown in world practice, but they are very promising. In addition, the work of graduate student V. Volgin, *Numerical modeling of a hybrid solar installation*, should be noted in this his work, the author calculates the parameters of the flow and heat transfer between a liquid and a wall containing a large number of small thermo-electric elements.

At the *Department of Heat and Mass Transfer Processes and Installations*, the application of the PHOENICS in the educational process takes place in the classroom of two disciplines: *Applied Software* and *Mathematical Simulation*.

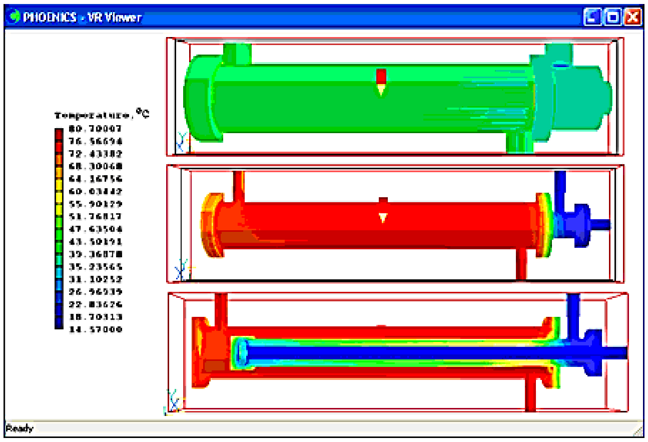
During lectures, the students get acquainted with the functionality of PHOENICS, including examples of its use when constructing geometric objects, depending on the coordinate system and the method of defining the grid; connection of thermophysical properties and corresponding modules for modeling the investigated processes; as well as the formation of an output file with the results of numerical modeling based on the control volume method.

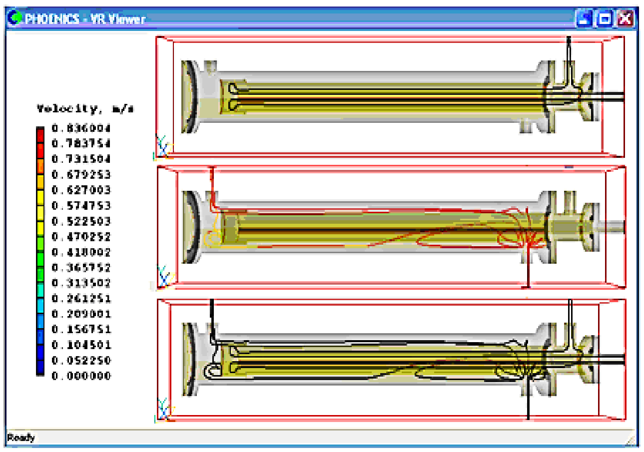
In practical and laboratory classes, students gain experience in using PHOENICS in solving problems associated with heat and mass transfer and, in particular, with heat, hydro and aerodynamic processes occurring in channels with different cross sections and reliefs on walls.

Graduate students of the department use PHOENICS in their scientific research. Maskinskaya A.Yu., Vlasenko A.S. and Arbatsky A.A. have carried out experimental and numerical modeling of heat transfer on surfaces with complex relief, and they have determined the expediency of its use in heat exchangers. The following figure shows the velocity field in the longitudinal-central section of the channel at the corridor arrangement of the holes (the coolant is water.)

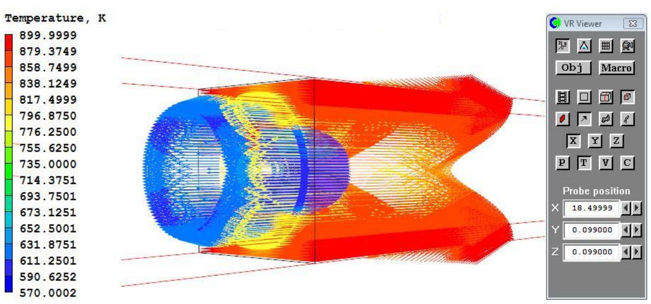


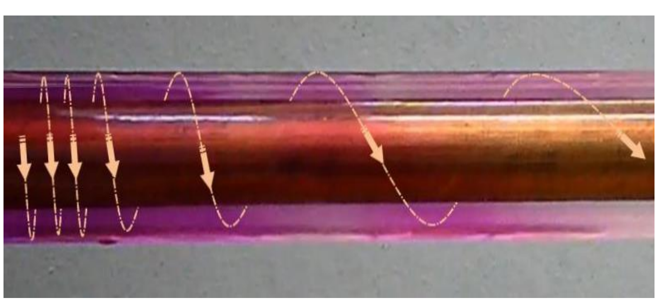
In the works of post-graduate students from Vietnam Hoang Khac Hoang, Vu Van Chien and Vu Sy Ky, the results of modeling, heat, hydro and aerodynamic processes occurring in thermal and high-temperature installations are presented. The following pictures show the results of simulating heat transfer in a three-channel heat exchanger.





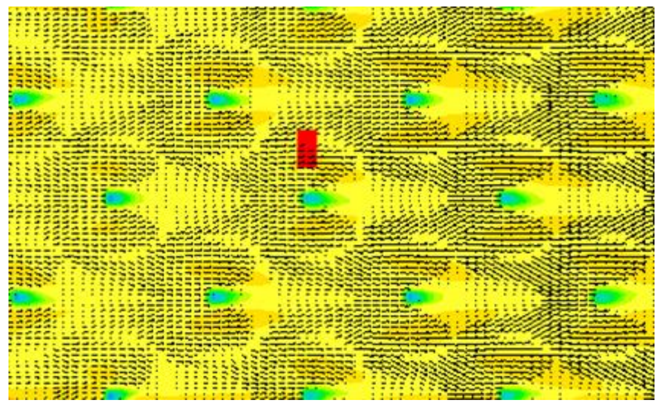
Whilst simulating the thermal-hydraulic process in a Field tube, the rotational motion of the fluid in an annular channel was found. It is shown in the following figures:



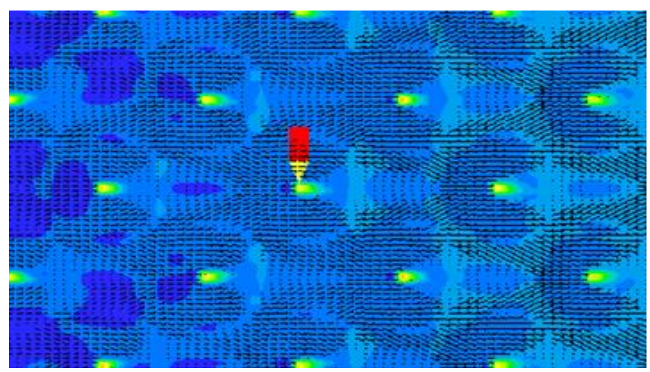


Graduate student Vu Sy Ky investigated the possibility of increasing the efficiency of a high-temperature installation by combining vortex heat-exchange intensifiers and breathable insulation in its outer enclosure. As a result of the simulation, it was established that air flows from one hole to others and that the air movement in the channels of the outer fence is helical. The following figure shows the distribution of temperature (A) and velocity (B) of air in the section z = 0.039 m above air-permeable insulation, equipped with cavaties with a bottom hole (C)

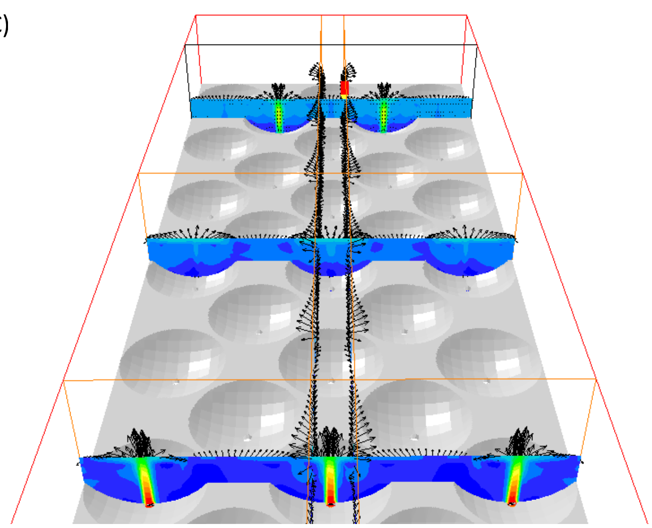
(A)



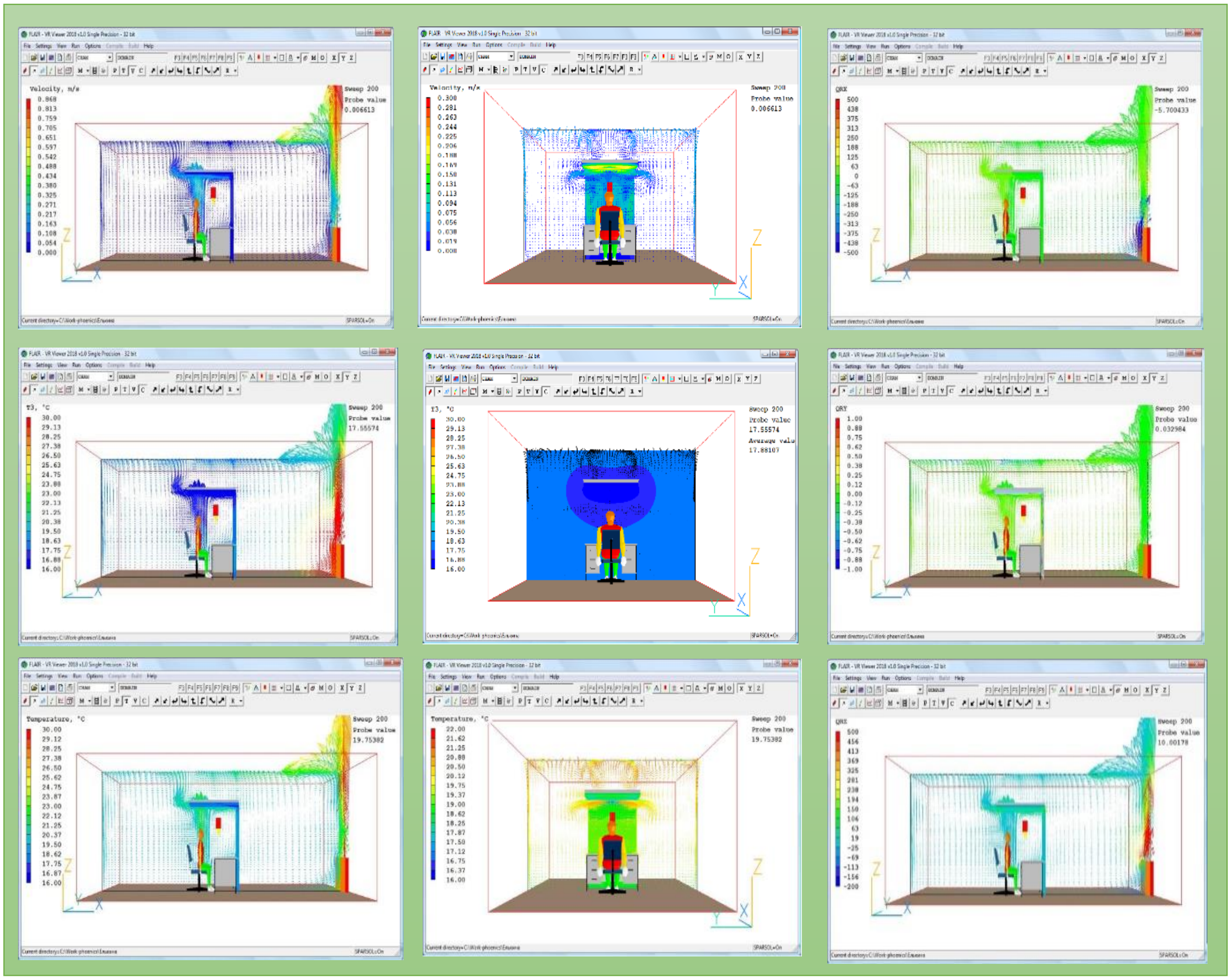
(B)



(C)



The work of graduate student Afonina G.N. is devoted to studying the feasibility of using a water-cooled panel to provide local thermal comfort in the area of human functioning. The following figure shows the results of simulating local heat transfer in a room with a cooled panel above a person's workplace and a source of thermal radiation.



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