PHOENICS Newsletter – PHOENICS at 40

CHAM

Dear Reader

Much has changed since Professor Brian Spalding accepted the post of Reilly Professor of Combustion at Purdue University in 1977. We were located far from the main campus in a freezing cold January with an horrendous wind-chill factor. For the first time, Spalding lacked a technician to code for him. Getting one would have taken time & better weather so – Brian being Brian – he taught himself coding.

By his return to England, in 1978, he had mastered the skill and was creating two major pieces of software: CHAMPION and PHOENICS. CHAMPION – a replacement for GENMIX free-for-use to academic institutions - did not move from the concept stage due to time constraints.

PHOENICS (Parabolic, Hyperbolic, Or Elliptic Numerical Integration Code Series) fulfilled Brian's desire to replace FLASH, TACT (and many application-specific codes) with one, general purpose, software which could be widely used – if it flowed PHOENICS could model it – and still can.

In October 1981 PHOENICS, the first commercially available Computational Fluid Dynamics (CFD) Software, came to the market via Concentration, Heat and Momentum Limited (CHAM), Spalding's Company, based at its current HQ in Wimbledon Village.

October 2021 marks PHOENICS at 40. PHOENICS has been joined by FLAIR (FLow in AIR), F1-VWT (used in academe to interest young minds in modelling cars) and, most recently, RhinoCFD which allows access to CFD modelling within the Rhino Environment.

PHOENICS became Brian's passion and part of my life since 1977 moving from idea, to possibility, to product. Spalding was ahead of his time. He foresaw the rise of scientific computing and, because of his prescience, became the founding father of CFD. He foresaw that it was possible to create a general-purpose scientific code despite the difficulties presented by the number of equations to be included. Others doubted but he persisted and thus created (with his team) the first available commercial code - the basis for most other CFD software.

PHOENICS is, we believe, the only CFD software still independently owned and distributed. It, and CHAM, have not (yet) been taken over by one of the more major players in the field.

This Newsletter contains memories and articles from CHAM, PHOENICS Agents and Users about what they have done, are doing, and what has happened over 10 years – and perhaps more.

It is appropriate that PHOENICS celebrates its 40^{th} birthday by moving forward whilst reflecting on four decades. This year PHOENICS is available on the Cloud (PHOENICS-OTC). PHOENICS-OTC provides a cost-effective, pay-as-you-go service, accessible from anywhere, without need for extra software or a licence. It is available on the Microsoft Azure Marketplace's selection of Virtual Machines (VMs) ranging from dual-core to 120-core VM options.

Why not check out PHOENICS-OTC and the 5-star review already received - *links on page 11.*

Kind Regards

Colleen Spalding, Managing Director

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Contents:

PHOENICS at 40, by John Ludwig, CHAM:

It comes as quite a shock to take stock and realise that if PHOENICS is 40, and I was at CHAM in pre-PHOENICS days, I must have been here for well over 40 years! Time passes quickly when one is busy, and PHOENICS has certainly kept us all busy over the years. As it is now 10 years since the last major birthday, I thought I would recap some of the major improvements that have been made.

It never ceases to impress me how prescient the original creators of PHOENICS were, as the basic structure they created, both for the Q1 and Earth solver, has stood the test of time well. One could compare PHOENICS to an old, well maintained, building – modern shiny plate-glass and chrome on the outside, but with Tudor oak beams holding it all up deep inside! A Q1 file from the very early days will still load into the VR-Editor and turn itself into objects with very little adjustment.

There is not enough space in a short article to list every change that was made. For those interested in the history of PHOENICS, a fairly complete list of year-by-year updates can be found at www.cham.co.uk/phoenics/d_polis/d_cron/chron.htm. Here I will list the more important changes over the last 10 years:

- VBO graphics in Editor and Viewer provide smoother shinier images
- HYPRE solvers provide robust, efficient parallel solutions of the equations
- Volume-Of-Fluid (VOF) models provide sharp interface capture for free-surface flows, including surface tension and contact angle
- Drift Flux Model (in FLAIR) provides validated aerosol deposition modelling
- Additional turbulence models:
    - Revised Wilcox 2008 k-ω model
    - Menter Baseline 1992 k-ω model
    - Menter SST (shear stress transport) k-ω model
    - Realisable k-ε model

All in high- and low-Reynolds Number form

- Scalable wall functions
- Solar illumination – the SUN object

There have also been numerous ease-of-use improvements both for pre-processing the in VR-Editor and post-processing in the VR-Viewer, including (in no particular order):

- Additional InForm and PIL commands
- Arbitrarily-shaped plotting surface for contours and vectors
- Additional Comfort Index calculations for FLAIR including Lawson Criterion
- Interactive auto-meshing
- Arbitrary domain-origin location
- Optional positioning of objects by centre coordinate instead of corner
- Line and fill for contour and iso-surface plots
- Colouring an iso-surface by the contour map of another variable
- Rain and Raingauge objects for wind-driven rain modelling in FLAIR
- Foliage object to represent drag, turbulence, heat and moisture sources & sinks due to trees
- Easy setting of domain-edge boundary conditions
- Parameterised multi-run in VR-Editor
- Better normalisation of residuals and better monitoring display during solution

In addition to the above, a plug-in for Rhino has been created, which allows users to generate, solve and visualise PHOENICS models completely within the Rhino environment, based on the underlying CAD geometry.

It will be interesting to see what the next 10 years bring!

Memories from PHOENICS Agents:

Applied Computational Fluid Dynamics Analysis: Computer Simulation of Fluid Flow, Heat Transfer, and Chemical Reactions, V. Agranat, ACFDA:

ACFDA, CHAM's Agent since 1998, provides PHOENICS software licenses, technical user support, training and CFD consulting services for private companies, public organizations, universities and research institutes.

Our mission is to solve client problems using the use of pragmatic CFD modelling by providing cost-effective and advanced CFD analyses. Examples of applications include green energy, hydrogen generation, environmental, nuclear, chemical and other industries.

Applied Computational Fluid Dynamics Analysis (ACFDA) is a computational fluid dynamics (CFD) software and consulting company located in Thornhill, Ontario, Canada. It operates in Canada, USA, Israel, Russia and Kazakhstan. ACFDA consists of a team of highly qualified PhDs each having more than 30 years' experience of teaching, research and industry in applied CFD.

Over the years, ACFDA has developed special-purpose CFD models based on PHOENICS and customized for specific client needs.

These advanced and validated models include: GRAD for gas release and dispersion modelling (http://www.acfda.org/docs/GRAD_for_CHAM_2009.pdf),

TPLUME for two-phase plume modelling (http://www.acfda.org/docs/Paper_ICONE22-30010_Agranat_et_al.pdf))

GLFLOW for analyses of complex gas-liquid flows (http://www.acfda.org/docs/GLFLOW_Capabilities.pdf).

WILDFIRE for modelling wildfire propagation (http://www.acfda.org/results/5IFBFC_Paper_2016.pdf, Mathematical modeling of wildland fire initiation and spread - ScienceDirect),

ACU3D and ACUTE for multi-scale simulation of thermo-chemical performance of ammonia cracking units and other customized models.

Links to more detailed information on these models are provided in Company News on www.acfda.org.

The partial list of long-term ACFDA's clients includes Brigham & Women's Hospital, North Carolina State University, Commercial Metals Company, Affiliated Engineers Incorporated, Natural Resources Canada (NRCan), University College of the North, A.V. Tchouvelev & Associates, GenCell Energy, Nazarbayev University and Tomsk Polytechnic University. Some comments on PHOENICS applications made by these clients are provided below.

A long-term and very successful collaboration between ACFDA and GenCell (www.gencellenergy.com) has been arranged over the past few years while applying PHOENICS to challenging multi-physics and multi-scale GenCell's applications. Dr. Vladimir Erenburg, GenCell's Senior Scientist, describes this project below. "I have warm memories of our fruitful cooperation with ACFDA on applying PHOENICS for GenCell's applications. (http://www.acfda.org/results/MSMofACU_R3.pdf).

PHOENICS customization with the help of Drs. Vladimir Agranat and Sergei Zhubrin from ACFDA to solve the problems faced by GenCell, and the intensive use of PHOENICS for CFD modelling associated with the development of various design and technological solutions, allowed us to achieve a deeper understanding of the complex physical and electro-chemical phenomena underlying the direct transformation of chemical energy into electricity, and develop a highly efficient ammonia generator.

GenCell's hydrogen and ammonia generator products are currently being tested and used in a number of countries in Europe, Southeast Asia, and North and South America. Of course, these words cannot convey all that was happening along with the development and use of a highly effective CFD tool

But there was the ardent desire of professionals of the highest qualifications to penetrate into the problem as deeply as possible and advance its solution as far as possible."

Dr. Andrei Tchouvelev and Mr. Benjamin Angers have been applying PHOENICS since 2007 at A.V.Tchouvelev & Associates Inc. to provide numerous hydrogen safety analyses for industry and academia. (http://www.tchouvelev.org/)

They say "Throughout the years we have used PHOENICS extensively for both research purposes and industrial applications to help resolve various issues related to the field of gaseous hydrogen safety.

From ventilation optimization to sensors placement or for comparison between CFD results and experimental data, PHOENICS provided us with a quick and efficient way to get the results we needed when we needed them, without the need for excessive hardware requirements."

Dr. Sam Matson, Director of Energy Technology at Commercial Metals Company has been using PHOENICS for more than 20 years. (https://www.cmc.com/)

He says "PHOENICS has been a valuable tool for me throughout my career. It has helped to optimize metal furnace burner arrangement, design and optimize industrial shop ventilation, design and optimize fume capture hoods, and understand and improve ductwork mixing.

There has been an impressive improvement in the speed and capabilities of PHOENICS over the nearly 20 years that I have used it and I appreciate the support and feedback from the team over the years."

Dr. Vladimir Agranat, President ACFDA, vlad@acfda.org

40 years of PHOENICS, by Dr Jalil Ouazzani, CEO ArcoFluid.

My first contact with PHOENICS was in 1986 when I was responsible for numerical modeling at the Center for Microgravity and Materials Research (CMMR) at the University of Huntsville in Alabama headed by Professor Franz Rosenberger (Fundamentals of Crystal Growth I – Springer Verlag, 1979). We were using FIDAP software; however we needed to deal with a large number of problems related to crystal growth: chemical vapor deposition (CVD), vapor phase transport (VPT), and solidification from molten baths. PHOENICS was the only software to deal with all of these problems at once. PHOENICS' competitor at that time, FIDAP, could deal only with incompressible flows and, besides that, we had the very professional CHAM NA team within a few miles (Steve Rawnsley, Ron Jewell, Michael Spalding and a lot of other wonderful people).

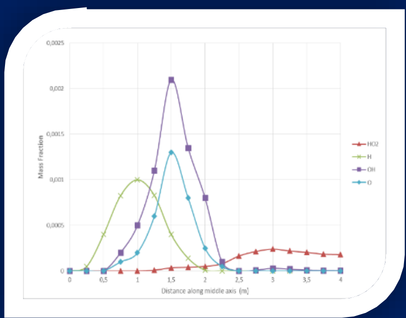
In 1989, I was able to work directly with Professor Brian Spalding during his visit to Huntsville, Alabama for the Seventh International Conference on Finite Element Methods in Flow Problems. We looked at the comparison between PHOENICS and FIDAP in the case of Boussinesq fluids in three-dimensional cylinders. We sat in front of the screen for several hours at the CMMR, running many cases. I didn't know at this time that we would meet again very often in Wimbledon, Moscow, Paris, Marrakech, Luxembourg, & Minneapolis during conferences and/or working groups. In 1992, back in France, I was contacted by the SNPE (Société nationale des poudres et explosifs) to model with PHOENICS software (but blindly) the case of a turbulent supersonic jet with chemical reactions to ensure that PHOENICS was well suited to their needs. I took up the challenge and, thanks to the open system of PHOENICS, I was able to couple PHOENICS with the DVODE of Laurence Livermore Laboratory which allowed me to process all the chemistry with the DVODE and insert linearized sources in the equations of species and energy.

It is necessary to introduce a special treatment for this kind of equation. Due to the very steep characteristics of partial derivative equations of species, a fractional step method was used: One solves for a cycle of time equal to 2Dt (Dt is CFD time step) in the following way:

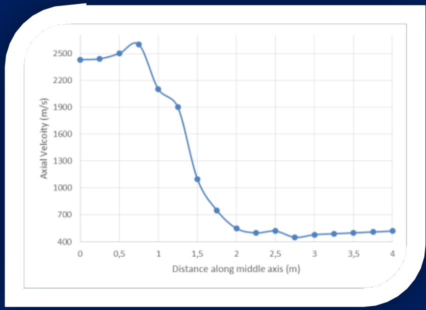
1) Solve in a first step scalar equations of concentration without source terms of chemistry.

2) Take as initial conditions the values previously calculated, and by neglecting the terms of convection and diffusion, solve a system of ordinary differential equations. Then adapt the Dvode solver from LLNL (Brown, 1989; LLNL Report, 1988)). This chemical resolution is made on a time step = 2Dt.

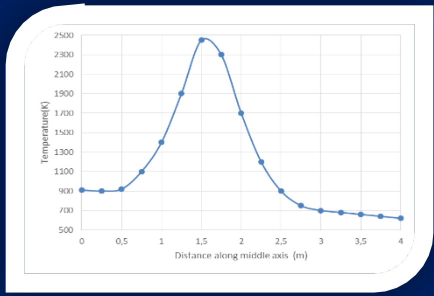
3) Finally, scalar equations are solved again with values obtained in step 2 as initial conditions. This resolution is made on a time step Dt. Figure 1 shows the chemistry module capabilities implemented into PHOENICS for this subject, for reacting jet experiments, reactive systems with a large number of chemical reactions with finite chemical kinetics and a large number of species. The test case chosen to illustrate such development was obtained from SNPE where experimental data were available. The results of the simulations fit well with the experimental measurements in this blind trial.



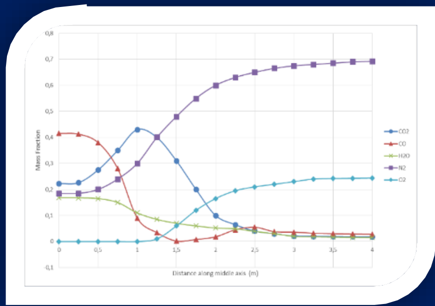
a) Chemical species (HO2, H, OH, O)



b) Axial centerline velocity of jet exhaust



c) Axial temperature starting from jet exhaust



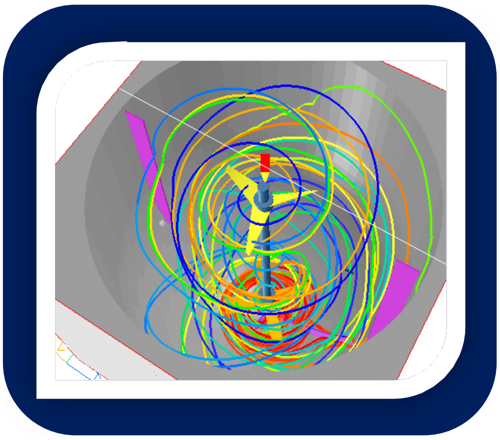
d) Chemical species (CO2, CO, H2O, N2, O2)

Figure 1. Representative Results of Simulation of Reacting Jets chemistry. The results fit well with the experimental measurements in a blind trial. Experimental data are property of SNPE.

After returning from the USA to France, my interaction with CHAM Wimbledon intensified and I was able to collaborate with people like Peter Spalding, Sylvie Stevens, Colleen King, John Ludwig, Mike Malin, John Smith, Steve Mortimer, Millie Lyle, David Glynn (the list is not exhaustive); from seminars, to specialized works, from simulations of fire in tunnels to heat transfer in datacenters, we tackled the most interesting engineering and research problems.

PHOENICS is not just a commercial software like many others on the market, but is the work of a CFD visionary - Brian Spalding. Around Brian many lives have been built, great successes have been achieved, great researchers have been born. PHOENICS provides specialists with a tool that is constantly being renewed and at the cutting edge of current algorithms; and neophytes with a simple and accessible tool to respond to concrete problems of industrial engineering. PHOENICS is a pioneer in virtual reality in the world of CFD, Cut-Cell techniques allowing simplified use of complex geometries that many other competing software wanted to copy without yet being completely successful, in turbulence models such as multi-fluid methods, in fluid-structure coupling for thermal expansions, in multiphasic methods (HOL, SEM, VOF, IPSA, ASM, GENTRA), in the movements of solid objects (Rotor, Mofor). This is not to flaunt the capabilities of PHOENICS which are more numerous than those listed above, but to draw attention to all the innovations that have been introduced there and which are or have been copied identically by many 'other well-known codes'.

To illustrate the above, here is an example of the use of the cut-cell technique (PARSOL) coupled with the MOFOR technique on two types of staged blades in a tank filled with a low-PrandtL liquid:



PHOENICS, although the software pioneer in the world of CFD, has managed to continue to improve and to remain an essential tool in CFD, robust, reliable and simple in its use. It remains as versatile as it is in this complex area of CFD where errors do not go unnoticed because its foundations have been well designed and thought out. I was able to realize this even more when I started to develop the VOF methods to introduce into PHOENICS in collaboration with John Ludwig.

The following methods are now available: CICSAM, HRIC, STACS, THINC-WLIC. The models developed up to now account for: Capillary forces, Marangoni effect, Static / Dynamic Contact, Angle Electrical Fields. For electric fields, PHOENICS by its open architecture allows a solution by coupling with the VOF method: flow based on Taylor's leaky dielectric model through the Laplace equation (Other models can be as easily introduced):

$$\nabla.(\varepsilon_0 \varepsilon \nabla V) = 0$$

And, the electric vector field **E** from:

$$\boldsymbol{E} = -\nabla V$$

PHOENICS will offer these same methods for three phases. This will allow extension of use to problems of evaporation, condensation, and surfactants.

For these forty years of PHOENICS, Happy Birthday.

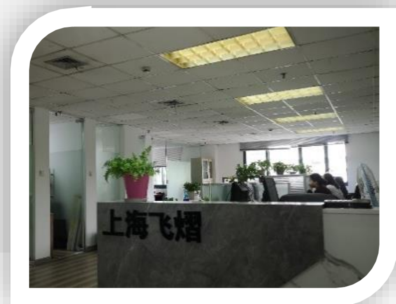
Dr Jalil Ouazzani, CEO ArcoFluid.

PHOENICS is 40, by Frank Kanters, Coolplug.

My first experience with CFD dates back to the early 1980s. During my mechanical engineering study, an older college friend of mine used the CORA program for his graduation thesis. It fascinated me enormously and led to my thesis later also in the field of numerical fluid mechanics. Although using a finite element method program, the seed for the field was sown. At that time I also heard that CORA no longer existed, it was now called PHOENICS and that Prof. Brian Spalding of Imperial College was the big man behind it. Many large companies in the Netherlands were users from the very beginning. In the first 25 years of my career, CFD played a much smaller role. Occasionally I would hire one of my older friends to model a flow or heat transfer problem with PHOENICS. This changed radically in 2006. I became CHAM agent for the DACH countries. It was good to see that Prof. Spalding was still the driving force and that all commercial CFD programs were based on his ideas. Over the years I have seen PHOENICS continue to improve. The possibilities and achievements have increased enormously since my student days. Every day I see "normal" engineers solving problems that seemed impossible a decade ago. I consider it a privilege to contribute to this. Good luck with the next 40 years!

40 years of PHOENICS, Fan Jinglong, Shanghai-Feiyi:

Congratulations to PHOENICS on its 40-year-old birthday. I am proud to announce that I have been a PHOENICS Agent/Reseller in China for over 25 years. I thank PHOENICS and thank CHAM - all my food, my clothes and my living come from PHOENICS. The photos are of my first office back in 2000 which was only 9 square metres, a visit by Colleen Spalding in 2017, and our current offices.



Memories from PHOENICS Users:

PHOENICS is 40, by Steven Beale, Jülich, October 2021.

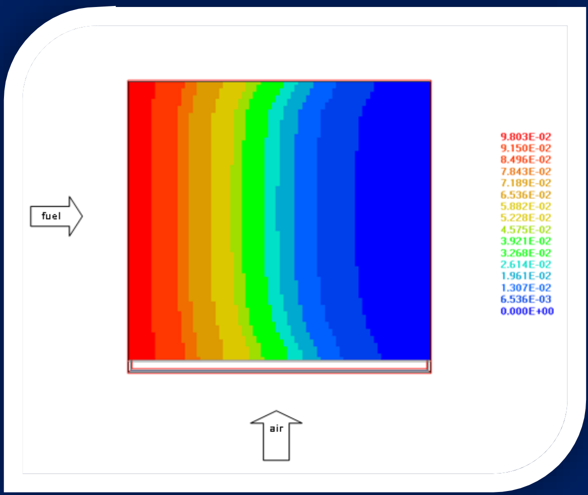


Figure 1. An early calculation with PHOENICS[1] for the local hydrogen distribution in a solid oxide fuel cell. 1.8s.

PHOENICS was the first general-purpose CFD code. At the time, many openly doubted it was possible, and that only specialized task-specific codes could be constructed. Brian Spalding and his CHAM associates, however, knew there was another way. They were correct. My first love back in the 1980s was (and still is) modelling heat transfer processes such as heat exchangers, and that was what I first looked at with PHOENICS back in 1986.

Pretty quickly, however we were looking at a diverse range of applications: to give a few examples; modelling PPE for the Health and Safety Executive (1987), extending the finite-volume method to consider stresses and strains (1991), viscous-plastic flow in wood digesters for the pulp and paper industry (1997), hydrogen fuel cells and stacks (2000), and membrane separators (2008). Because of the open architecture of the code, it was also quite suitable for trying out more fundamental numerical ideas on, for instance 3-D stream functions or stream-wise periodic problem formulations, something that was not possible with many of the other commercial codes that had followed. When one looks around today and sees the whole range of extraordinary applications being solved with CFD, it is rather incredible to think just how many of them were first done with PHOENICS. This was certainly true for our own ideas on hydrogen fuel cells and those of many others, not mentioned here, too. Of course, time stops for no one, and today's engineers are perhaps too busy solving the very complex problems of the day to look back and see the remarkable technical achievements that were achieved with the original general purpose CFD code suite over four decades. It is reassuring that at 40, PHOENICS is still going strong. I would imagine it will be at 60 and 80 too, and that it will continue to contribute in no small way to Brian Spalding's vision of using, previously inconceivable, computer apps in a vast array of human activities and interactions, a vision which we can see, little-by-little, coming to pass.

Steven Beale, Jülich, October 2021.

1. S.B. Beale and W. Dong. Technical Report No. PET-1515-02S, National Research Council Canada, Ottawa, 2002.

Uses of PHOENICS in MPEI, 2011 to 2021, by A. Ginevsky:

1) *Simulation of evaporation of water from a Petri dish.* Authors: M.A. El Bouz, A. Ginevsky, A. Dmitriev

The task was formulated taking into account the following processes:

a) Cooling of water surface due to evaporation;

b) Dependence of evaporation rate from surface temperature;

c) Dependence of natural convection from temperature and concentration of water vapor;

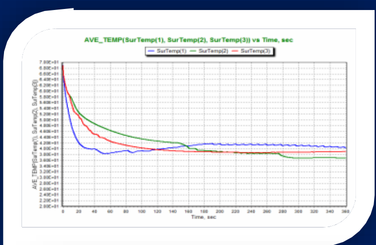
d) The Petri dish was placed on a heated plate;

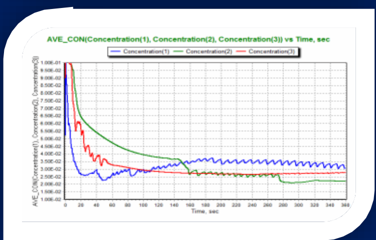
e) A wall was installed around the Petri dish with radius of domain;

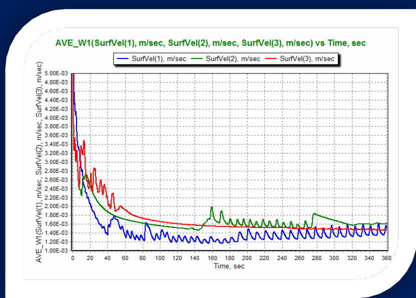
f) OUTLET boundary conditions were used on top of the domain with relevant parameters.

The task was solved as transient in cylindrical coordinate systems.

The following images contain temperature, concentration of vapor and velocity over water surface after averaging on the water surface.







Different temperatures were calculated at the top boundary condition (20, 60 and 40 Celsius). Image analysis demonstrated that water surface evaporation can have stochastic characteristics which depend on the flow structure changing.

A more detailed view of processes can be seen on video (see files on Yandex.Disk at folder 'task1' Conc.avi,Temp.avi and Vect.avi). It is interesting that temperature difference along the surface of water can be about 1 degree.

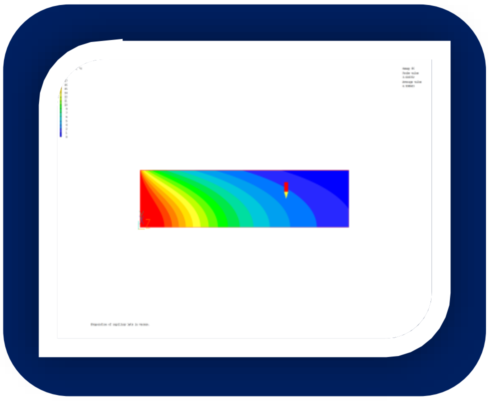
NB: The link for all external files on Yandex.Disk for PHOENICS News is https://yadi.sk/d/m2kVP9eSv-q18A

2) *Cooling of a thin water jet, which moves at very low external pressure.* Authors: A. Boucharov, E.Vishnevsky, A. Ginevsky

Monodispersal-system technologies can use capillary break-up of very thin liquid jets which can move in different conditions. Jet velocity can be very high; for example, a water jet of diameter 20 mkm can have a velocity of 10-20 m/s at laminar regime.

A jet with such a diameter can be several centimeters in length. Moving a jet into an environment with very low pressure can lead to very fast cooling of water due to evaporation from the jet surface. The task was solved as steady state in a cylindrical coordinate system.

The temperature distribution calculated, is shown in the figure below:



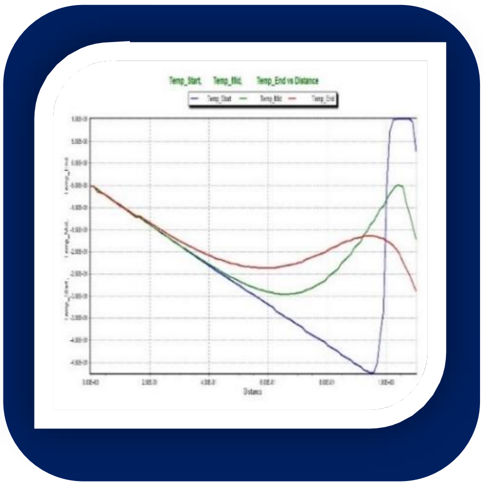
The temperature distribution shows that the jet surface cools very quickly as does the jet itself.

3) *Freezing of a water layer on the surface of ice.* Authors: A.-M. Baronenkova, A. Ginevsky

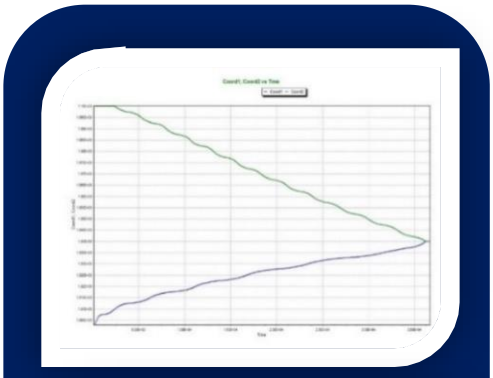
The study is of the freezing process of a layer of water on the surface of ice. The water layer has a thickness of about 0.1 m and an initial temperature from 10 to 70 degrees Celsius. The environment temperature above the ice is about -50 C. The ice has thickness is about 1 m or more with some initial non-uniform temperature distribution.

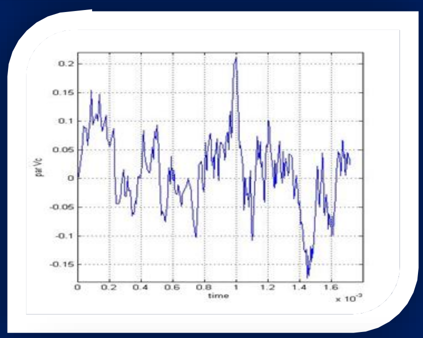
The movement of freezing fronts was investigated. For calculation of freezing process model of Prakash was used. The transient task was solved for 1D Cartesian coordinate system.

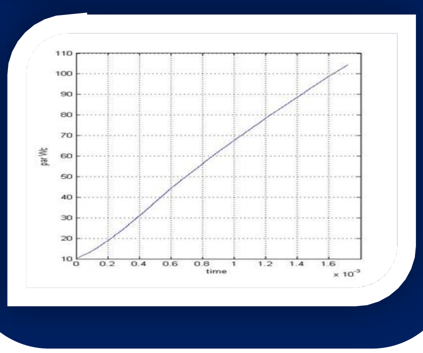
Temperature distributions at various times are shown in the following figure.



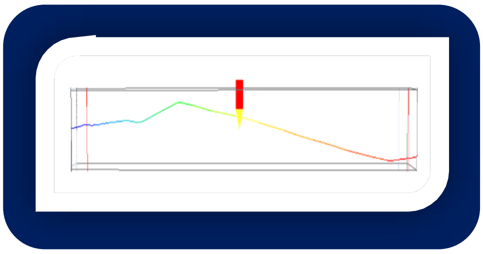
A special program was created to process calculation results produced by PHOENICS. This program allows calculation of the coordinate of the freezing front at each time. Results of calculations for freezing front are shown on the following figure:







The first figure proves that X-velocity of particle varies from -0.16 to 0.15. The second figure shows that velocity along the tube is increased. One trajectory is shown in the following figure.



According to data on the figures, the use of granules accelerates cooling.

4) Movement *of small granules in turbulent flow in the thin tube.* Authors: T. Murtazin, A. Ginevsky

Renewable hydrogen targets are used to study rare events when proton streams interact with targets. The renewable hydrogen target in this case is a stream of hydrogen granules with a size of several microns moving in a tube with a diameter of about 1 mm. The speed of gas flow in the tube varies significantly from 10 meters per second to hundreds of meters per second. The gas flow is turbulent. Under these conditions, the granules can interact with the gas flow and change their trajectory. GENTRA was used to investigate motion of granules.

The following figures demonstrate velocity of granule for one of realization.

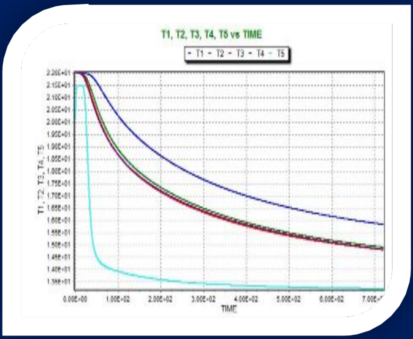
5) *Cooling a kidney for transplant purposes.* Authors: A. Boukcharov, A. Ginevsky, E. Pliner

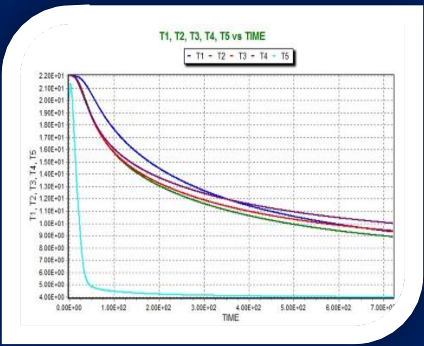
When transplanting a living organ, it is very important to slow down all processes to solve the problem of rapid cooling of said organ. Usually, the cooling process is carried out by passing cold liquid through the organ; in this case a kidney. Instead of calculating a kidney with a real geometry, a simplified geometric model was chosen, which has approximately the same hydrodynamic resistance and heat capacity as an ordinary kidney.

The calculation of kidney cooling was carried out taking into account that the structure of the kidney is mainly porous and some heat can be accumulated by the solid part of the structure.

In this study, it was presumed that ice granules move with the fluid, which should contribute to faster cooling of the kidney. For the melting of granules, a special model was developed and implemented using InForm.

The dependence temperature in five specific points in the kidney vs time is shown in the following figures at different number of ice granules (10^5 and 10^9).





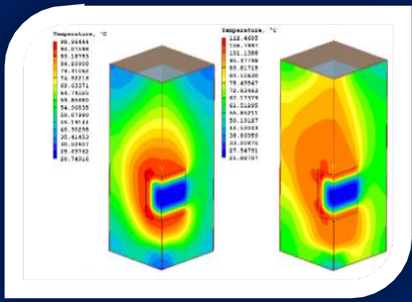
Task 6. *Modeling the fog formation in an electronic cigarette.* Authors: Ya. Volgin, A. Ginevsky

The sequence of processes in an electronic cigarette can be represented as follows.

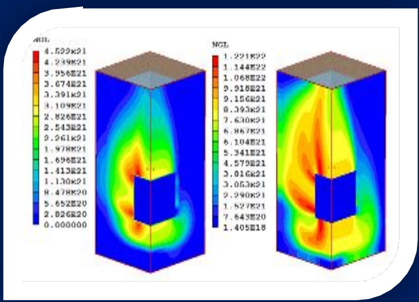
For some time, an electric current is supplied to the heater. The heater contains a porous material with a liquid, which contains a mixture of water, glycerin and other additives. When the liquid is heated, it begins to evaporate rapidly.

The boiling points of the individual components of the mixture are different, therefore, some of them begin to condense from the evaporated mixture of gases. Small droplets of mist are formed. In this work, only the main components, water and glycerin, were used for the calculations.

The following figure contains temperature distributions at 0,4 and 0,5 seconds after beginning of heating.



The following figure demonstrates distribution of concentration of droplets, which are formed due to condensation in the same time moments.

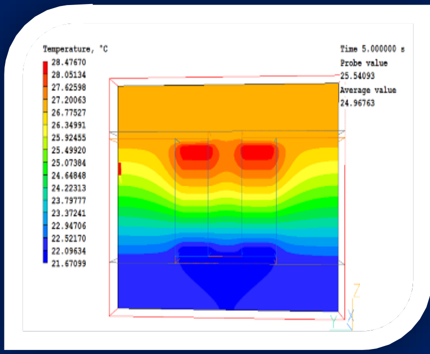


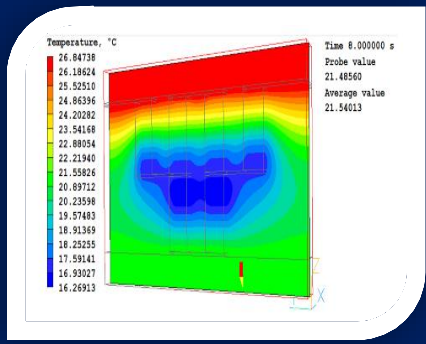
7) *Investigation of working regimes of multi-cascade thermoelements.* Authors: V. Volgin, A. Ginevsky

Steady and transient regimes of multi-cascade thermoelements were studied. The subjects investigated were: time to achieve a quasi-steady state, temperature distributions at various time moments etc. The following physical effects were taken into account: heating due to electric current, cooling on cold junctions, heating on hot junctions, heat conductivity etc.

A Simulation Scenario for PHOENICS-Direct was created to carry out calculations. The User of a Simulation Scenario is able to change material and properties of thermoelements, value of current and composition of its harmonics, number of cascades (from 1 to 3), grid etc.

The following figure demonstrates temperature distributions for one-cascade and two-cascade thermoelements at various steps.





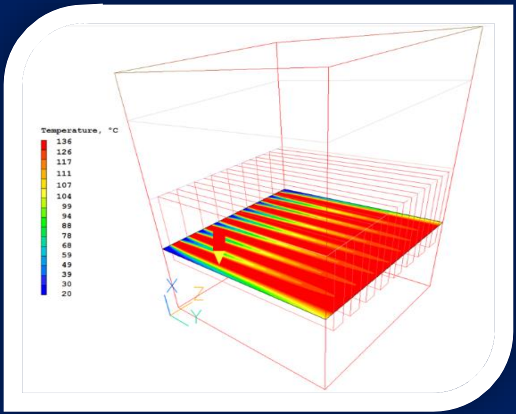
8) *Investigation of microchips cooling by air flow*
Authors: M. Ageev, A. Ginevsky

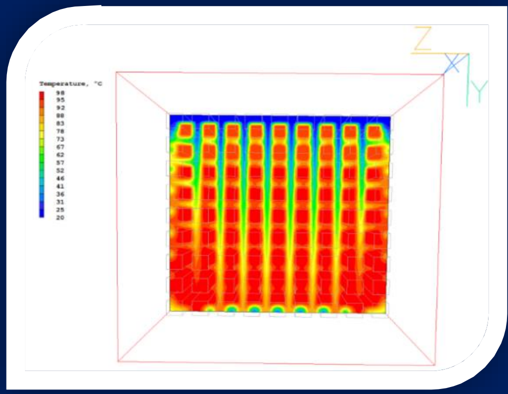
Effectiveness of modern electronic devices depends on amount of heat which can be transferred to the environment. If we take into account the fact that size of devices decreases very fast then it is clear that problems with heat sink from electronic devices will increase.

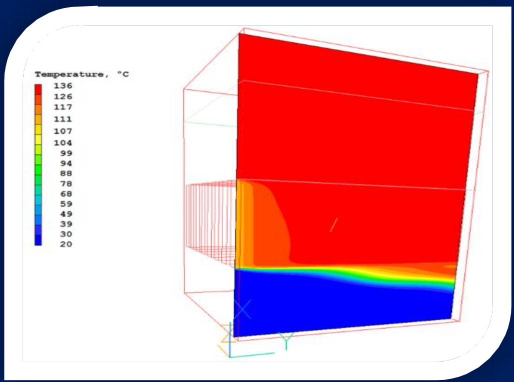
The air-cooling system for a bipolar diode was investigated. Two variants of heat exchanger were used: one with cooling fins and one with cooling needles.

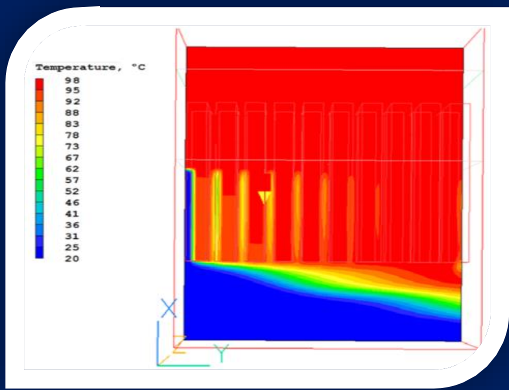
A Simulation Scenario was created for both construction variants. The SimScene User may choose the construction variant, number and size of fins and/or needles, speed of air flow, and power of heat source. The task was solved as steady conjugate heat transfer.

The following figures demonstrate temperature distribution for both construction variants.









PHOENICS at 40, by Dr Bob Hornby:

I started to use PHOENICS in the early 1980s and I am still using it today! Prior to PHOENICS most fluid flow codes were tailored to the current application and so a new code had to be written for each new application. PHOENICS was the first general purpose CFD (Computational Fluid Dynamics) code and provided a fixed framework for any application. It also allowed the inclusion of source terms of any complexity.

Throughout the 1980s and early 1990s I was working in the Nuclear Industry on problems relating to the British Advanced Gas Cooled and liquid sodium cooled fast breeder reactors. PHOENICS found many applications relating to the thermal hydraulic performance and safety of these reactor systems.

I then spent many years working in the Defence Industry where knowledge of the ocean environment was of particular importance. In particular ocean eddies, fronts, surface and internal waves and turbulence were all of interest as they affected, for example, the performance of underwater sonar. PHOENICS proved equally useful in analysing these new types of flow and some of the work on internal waves was reported in the PHOENICS Journal and at CHAM hosted international conferences.

On retiring I still retained use of PHOENICS and started to contribute to the PHOENICS Newsletter. The topics I chose were usually stimulated by current events, though the first one was encouraged by the RNISR (Royal Netherlands Institute for Sea Research). There, scale experiments were being conducted to investigate the 'dead water effect', the situation where under certain circumstances the generation of internal waves by a surface vessel in a stratified sea can dramatically reduce its speed.

The experiments were successfully modelled by PHOENICS and formed part of Professor Spalding's presentation at the Philadelphia CFD Conference in 2010, figure 1.

Figure 1. Slide on the 'dead water effect' from the presentation by Professor Spalding at the Philadelphia CFD Conference in 2010

The work was reported in the Spring 2009 PHOENICS Newsletter. Summer seas, lakes and rivers or fjords discharging into the sea all produce a stratified water mass. So this work was extended to see if a swimmer in stratified water was at risk of drowning due to this effect (some experiments on an actual swimmer in a stratified swimming pool had been conducted by the RNISR indicating a possible effect). The swimming body represented in the PHOENICS model is shown in figure 2 and results were reported in the 2010 PHOENICS Newsletter. The body and head were simply represented by rectangular, solid frictionless objects. The propulsive effect of the moving arms and legs was achieved using embedded, moving momentum sources.

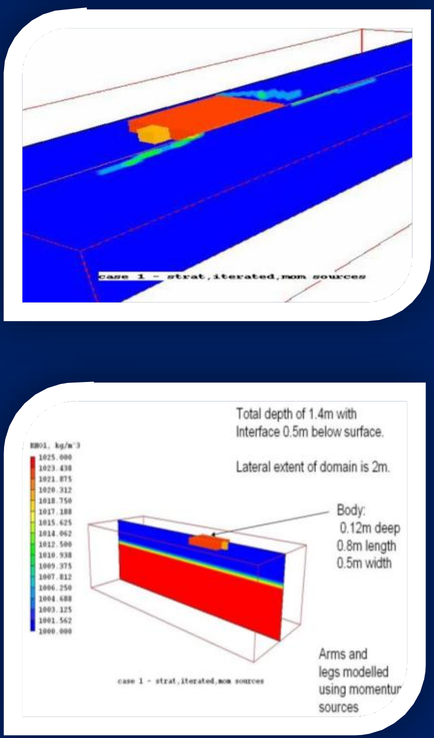
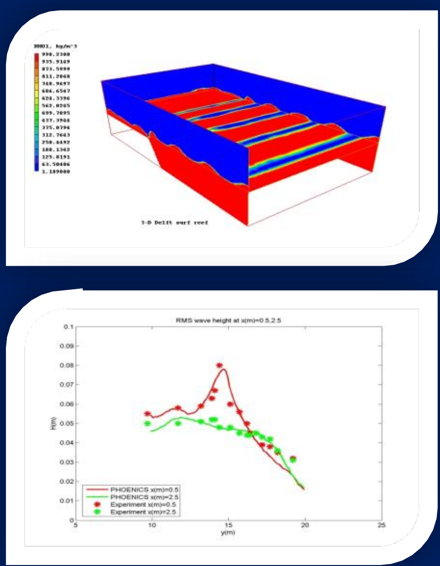


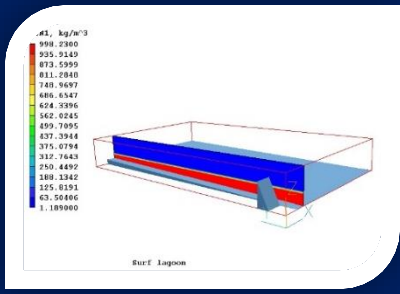
Figure 2. Representation of a swimmer swimming in stratified water with moving arms and legs.

The articles in the Newsletter in the Summer 2011 and Winter 2012/2013 were stimulated by a local event, the building of an artificial surf reef off Boscombe beach to attract tourist revenue from surfers. This led to use of the PHOENICS SEM (Scalar Equation Method) to model the surface waves arising from underwater reefs. Initial checks were made on SEM by comparing with the MOC (Method of Characteristics) for simple geometries before more extensive 3-D tests were made against laboratory measurements conducted in the wave basin of the Civil Engineering Department at the Delft University of Technology. The favourable comparison of PHOENICS simulations with experimental results in the wave tank are shown in figure 3.

An artificial surf generator such as at the world's first inland surf lagoon at Dolgarrog in Wales was also modelled.using the SEM and MOFOR. This facility expects to attract near 75,000 people every year and host international surfing events featuring the world's best surfers. The surf park employs a unique wave generating technique – a moving wave foil that produces powerful and consistent waves of varying heights up to 2m in a 300m long by 110m wide lagoon. Simulation details are given in the 2015 Newsletter (see figure 4).



(4a)



(4b)

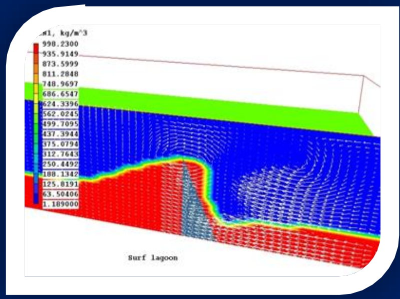


Figure 4a: The wedge object representing the wave foil shown positioned in the simulation domain (with sloping bottom).

Figure 4b: Density distribution in a vertical plane at the wave foil showing the formation of a 2m hiah wave after 1.8s.

The SEM was also used to model the performance of TSWDs (Tuned Sloshing Water Dampers) used in the 162m high Brighton i360 Tower to damp the vibrations caused by wind buffeting and vortex shedding. Details of these simulations are in the Spring 2017 Newsletter. . A later use of the SEM in 2017 (Newsletter 2017) looked at the topical subject of tsunami formation after the catastrophic events in Japan in 2011 caused by an underwater earthquake.

In the Summer 2014 Newsletter, PHOENICS simulations were compared to earlier work (relevant to sonic bangs) involving MOC computations of supersonic flows. These were flows in which the vibrational modes of oscillation of the gas molecules become important. This necessitated an additional time dependent equation in PHOENICS to model the vibrational energy content of the gas.

However, it is not easy to conduct an experiment in which the same swimmer exerts equivalent strokes in stratified and non-stratified pools and so it is difficult experimentally to prove there is an effect. But the results from the simulations indicated no discernable effect of the stratification.

A typical flow pattern for the steady 2-D flow of nitrous oxide gas at a Mach number of 1.56 is shown on the top of figure 5. The bottom of figure 5 shows the good agreement obtained by the PHOENICS simulation (using a BFC grid) with the MOC for the flow through the shock wave.

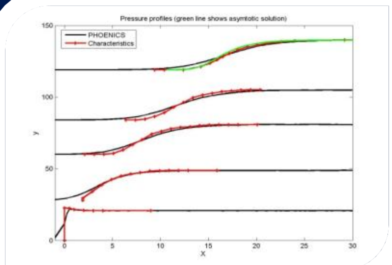


Figure 5 (top): Interferogram of the steady 2-D flow of nitrous oxide at Mach number of 1.56 past a wedge whose upper surface is inclined at 2⁰ to the freestream.

Figure 5 (bottom): Comparison of PHOENICS pressure results (dark lines) with the MOC (red crosses). The green line shows the exact far field solution.

The proposal for construction of an extensive wind farm off the Bournemouth coast prompted an interest in wind turbines so the earlier method of moving momentum sources was applied in PHOENICS to the flow through the moving turbine wind vanes, modelling turbulence with a k,ε turbulence model. The surface of each rotor was subdivided into a set of 2-D panels each of which contributes a momentum source depending on the panel area and the local lift and drag coefficients. PHOENICS results were compared with experiments undertaken in Denmark on two Nibe wind turbines 40m in diameter with a hub height of 45m and separated by 5 diameters in a neutral atmosphere. The comparison with the PHOENICS results for the axial wind velocity are shown in figure 6 (top) and for the turbulence intensity in figure 6 (bottom).

The upstream PHOENICS results agree very well with the similarity function and reasonable agreement is also obtained for the experimental velocities at 1 diameter and 2.5 diameters downstream of the turbine. Turbulence intensities (derived in the PHOENICS results as the square root of two thirds of the turbulent kinetic energy) are compared at 2.5 diameters downstream giving similar agreement on levels. Full details are in the 2014 Newsletter.

More recently, it has been shown how the MOFOR concept can be adapted to allow modelling of a moving body acted on by specified forces (Newsletter, Winter 2019/2020). This provides a means of investigating more realistically aspects of the 'dead water effect' applied to vessels moving in stratified water.

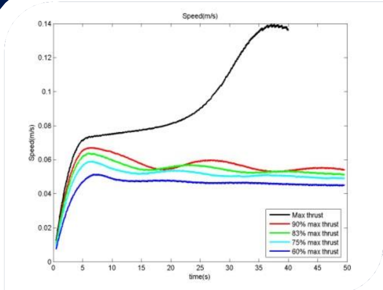


Figure 7. Propelled body speeds at various thrust values as a function of time.

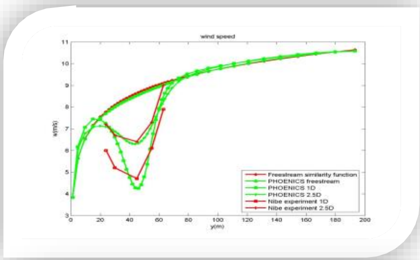
Figure 7 shows the results obtained from PHOENICS simulations (using the modified MOFOR capability) of a model body moving under the action of specified propulsive forces in a stratified tank. Full details are given in the Autumn 2020 Newsletter, but the figure shows how significant fractions of the propulsive power go into internal wave radiation, with consequent enhanced drag and reduction in speed.

All in all, a long, varied and informative use of PHOENICS!

Dr R P Hornby
bob@hornby007@gmail.com

An interesting diversion in 2016 saw PHOENICS applied to modelling crowd behaviour. Many crowd crush disasters have occurred in the past, over 2000 deaths were recently reported in a stampede on 24th September 2015 as pilgrims were en route to the Jamaraat Bridge in Mina, Saudi Arabia, near Mecca.

The PHOENICS simulations used a crowd pressure related linearly to the crowd density (compressible flow) and source terms in the momentum equations for the motive force and drag on individuals. The simulations produced quite plausible results for crowd behaviour. The 2016 Newsletter gives full details.



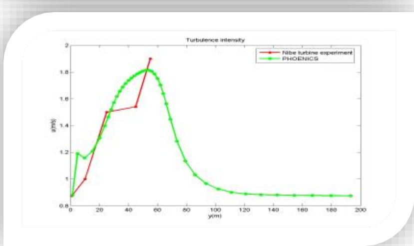


Figure 6 – Top: Comparison of PHOE

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PHOENICS-OTC may be new to the market but has had its first, 5-star, review:

https://azuremarketplace.microsoft.com/en-us/marketplace/apps/concentrationheatandmomentumlimited1616154387047.phoenics?tab=Reviews

CHAM, back in the day:

(CHAM).

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