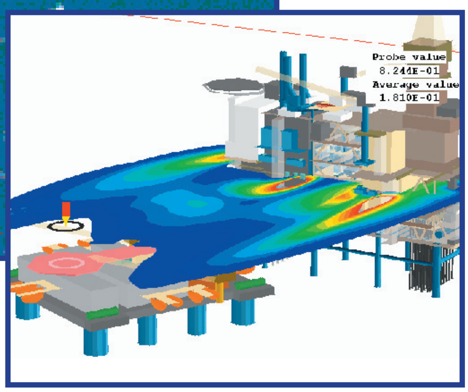
PHOENICS

News

Spring 2005

From the pioneers of CFD.



Editorial

BROADENING THE HORIZON

2004 was an especially busy year for CHAM development personnel with effort concentrated on the PHOENICS-3.6 release, announced in the Autumn Newsletter, and the upgrading of some special-purpose variants such as the FLAIR (building services) and ESTER (aluminium smelting) modules. Details of the recent updates are outlined later in this newsletter.

1) PHOENICS Commander

We have also been paying particular attention to first-time users of PHOENICS, for whom we have provided a greatly-enriched version of the PHOENICS Commander. This now serves as an informative and easy-to-use gateway to all PHOENICS capabilities.

The new Commander is structured so that some users will be able to use their own language rather than English. At present, this facility is embryonic, with priority given to Russian, which is being used as the trailblazer because it presents the difficulty of requiring a different character set.

However, when this first non-English language is well established, extensions to other languages will follow quickly.

2) Fluid-structure interactions

It is widely believed that the use of finite-element codes for solid-stress analysis and of finite-volume ones for fluid- and heat-flow is necessitated by a fundamental difference between the physics of solids and fluids.

This is not so, as has been demonstrated by recent developments in PHOENICS, which has been able to simulate solids and fluids simultaneously since 1991. Admittedly, the algorithm then in use (a form of SIMPLE) proved to converge slowly; and did not handle bending very well; but a new algorithm has removed both shortcomings.

Since PHOENICS is the only CFD code, which possesses this multi-physics capability, it is intended to make fluid-structure interactions a field in which much PHOENICS development is concentrated.

3) Solids moving through fluids

Another aspect of fluid-structure interactions is their relative motion, for which PHOENICS has possessed the MOFOR facility for several years.

This too has been improved, especially in relation to its combination with PARSOL for curved bodies; and further extensions are planned. Ultimately it will be possible to calculate how both the motion of the solid body, and the stresses within it, are influenced by the force exerted by the fluid.

4) The PHOENICS 'Wave Tank'

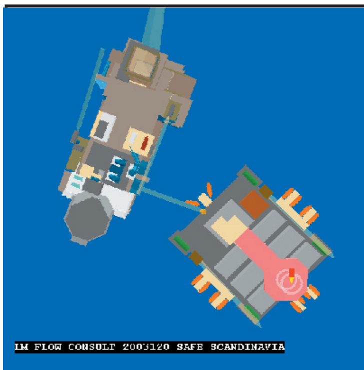
Recently CHAM was asked to assist in the simulation of a device for extracting energy from ocean waves. Rather than create a one-use-only ad hoc model, CHAM chose to create a 'Computational Wave Tank' which can be used for all the purposes for which physical wave tanks are now used:

- *prediction of wave forces on oil platforms;*
- *the modelling of ship and submarine motion; etc.*

What is worthy of mention is that this 'virtual tank' was created without any new Fortran coding whatever. All was done by way of In-Form statements inserted into a (quite small) Q1 file.

In-Form is proving to be invaluable for those users of PHOENICS who have novel problems, and who do not wish to create (or ask CHAM to create) the formerly necessary specialised coding.

Brian Spalding – Email: brianspalding@cham.co.uk



CONTENTS

Front Page:
"SAFE Scandinavia"
Picture courtesy of
LM FlowConsult

WHAT'S NEW IN PHOENICS-3.6.1

PHOENICS-3.6.0, outlined at: www.cham.co.uk/phoenics/d_polis/d_docs/tr006/tr006.htm has been updated in the following ways:

VR-Editor

- Individual wall-functions for PLATE objects
- Individual surface-roughness for PLATE objects
- New WIND_PROFILE object
- Attribute changes can be propagated through a group or multiple selected objects
- Objects can be re-ordered in Object-Management Dialog
- Fire heat source as power of time in FLAIR FIRE object
- New comfort indices for FLAIR - Draught rating, Percent Productivity Loss
- Implementation of FLAIR DIFFUSER objects improved

VR-Viewer

- Vector width can be set in pixels
- Maximum vector length can be set
- Source/sink information from RESULT for each object can be displayed from context menu Earth
- Integer holding fate of GENTRA particle made available in GENIUS
- Accuracy of particle volume fraction improved for GENTRA

Bug Fixes

VR-Editor

- Freezing of FLAIR FIRE object dialog when incompatible options selected fixed
- Missing scalar sources for FLAIR PERSON/PEOPLE objects fixed
- Creation of sub-objects for FLAIR DIFFUSER (displacement) object fixed
- Array copy now obeys 'object limited by domain' setting
- Grid in 'Edit all regions' dialog now obeys 'object limited by domain' setting
- Crash due to insufficient array size when reading large binary STL fixed

VR-Viewer

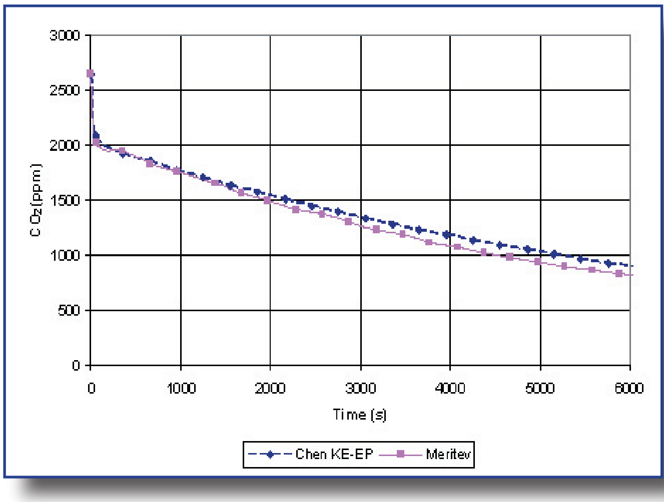
- Probe no longer linked to object position when several objects are selected in Object management dialog
- Colour palette no longer corrupted after saving streamline animation

Earth

- Internal inlets/outlets with MOFOR active fixed
- Missing transient term for all scalars when MOFOR active fixed
- Size of intermediate PHI files dumped during MOFOR run greatly reduced
- Areas and volumes held in STORE(AREE,AREN,AREH,VOLU) no longer set to zero in blockages, and updated with cut-cell values for PARSOL
- Errors in conjugate heat transfer with PARSOL fixed
- Error in treatment of Fine-Grid-Volume object fixed

VALIDATION OF FLAIR

The Laboratory for Heating, Sanitary & Solar Technology at Ljubljana University has validated PHOENICS/FLAIR against their measurements of velocity and CO2 concentration in an office environment purged by clean-air jets and directed towards an occupant seated at a desk. A steady-state flow and thermal solution was produced, and then this was used to initiate a transient simulation of the purging of a uniform distribution of CO2 from the room by clean air.



The plot shows the measured and predicted decay of CO2 concentration at a specified location in an office as a result of dilution by uncontaminated air jets.

NEW

STANDALONE PHOENICS VIEWER

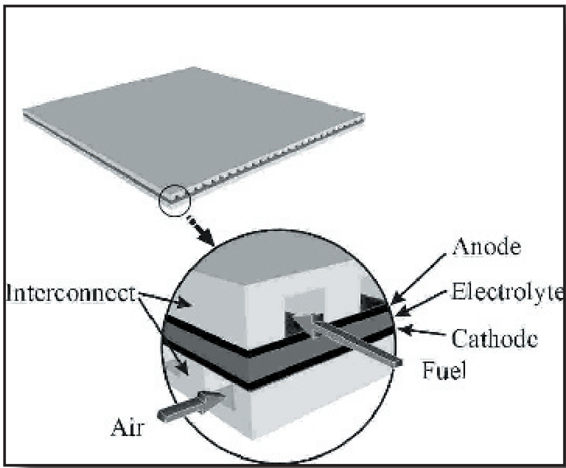
PHOENICS licensing options have been extended to offer the VR-Viewer as a stand-alone product, enabling clients to display and present results on multiple systems whilst retaining the solver elsewhere. PHOENICS On-Line users will benefit similarly.

Prices for the VR-Viewer start from £500 – contact sales@cham.co.uk for further information

FUEL CELL RESEARCH

Fuel cells have become the subject of much interest as a potential low-carbon-fuel substitute for conventional heat engines. Canada is currently a world leader in the development of modern fuel cells. Researchers at the National Research Council of Canada (NRC) have been using PHOENICS and other codes to model fuel cells since 1999.

A fuel cell is an electrochemical device, which converts hydrogen-rich fuel and oxygen to electricity (and heat). Unlike a battery, a fuel cell does not require re-charging. Fuel cells are typically operated in stacks in order to increase the operating voltage. We have studied both high-temperature solid oxide (SOFC's) and low temperature proton exchange membrane fuel cells (PEMFC's). The temperature distribution is critical to the operation of both PEMFC's and SOFC's.



Schematic of passages in a typical solid-oxide fuel cell

Several CFD code vendors are actively developing detailed fuel cell modules for performance calculations of the hydrodynamics and electrochemistry within the passages of fuel cells for applications in the automotive and stationary power industries.

The main problem with the conventional approach is that enormous meshes are required, to perform flow-field calculations within the numerous passages of the fuel cell. Moreover these flow fields are for the most part quite uninteresting; simple internal flow in curved ducts, hardly worthy of the full solution of the pressure-corrected momentum equations.

We have therefore taken a different approach, and used the unique features of PLANT, and the Multiply-shared Space (MUSES) method originally developed to model heat exchangers, to perform calculations in planar SOFC's based on a 'distributed resistance analogy'.

In this methodology the bulk motion of the fluids is simulated, but the fine detail is lost. Fuel cells are more complex than heat exchangers. Electric field potential is affected by three main factors:

(i) charge transfer also known as activation (kinetic) losses which occur at low currents,

(ii) Ohmic losses associated with Joule heating in the ionic and electronic conductors at intermediate currents, and

(iii) mass transfer limitations in the gas passages and porous diffusion layers that can be very important at large current densities.

Thus it is necessary to include iterative computations for the electric field and current density that are a non-linear function of temperature and mass fraction of the fuel and oxidant, as part of the overall calculation procedure. Modification of inter-phase transfer coefficients as a function of wall mass transfer effects is also incorporated.

Results based on the MUSES method have been validated carefully against detailed simulations using fine meshes. Agreement is excellent. We are also exploring the use of the PARSOL cut-cell technique to perform detailed calculations in PEMFC's, for which we are simultaneously developing experimental and numerical results in order to create a high quality database for future basic research and code validation.

Dr Steven Beale, National Research Council of Canada

Email: Steven.Beale@nrc-cnrc.gc.ca

CHAM CONSULTANCY UPDATE

CHAM's consultancy team continues to be employed on a wide variety of interesting applications. Perhaps none more so than the groundbreaking project with Centro Sviluppo Materiali SpA (CSM) completed earlier this year.

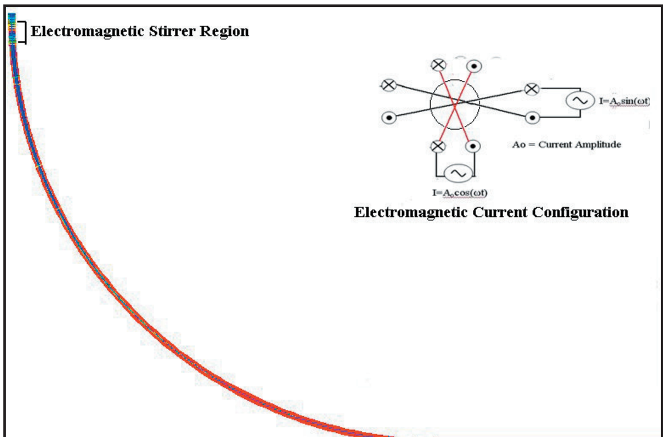
The project was concerned with the creation of a 3-dimensional mathematical model of a continuous-casting process, incorporating solidification and electromagnetic braking of steel. The model permits the simulation of casting and solidification in a curved domain, involving an electromagnetic stirring action with a pre-defined coil current. Mick Hughes reports …

Electromagnetic stirring of steel during continuous casting of billets and slabs is a well-established technique that improves the quality of the cast products by stirring the molten pool. Mixing of the liquid metal positively influences the solidification process at the microscopic crystal level helping to make the final cast less brittle.

A model was developed to provide a means to study the large scale electromagnetically influenced flow and thermal behaviour in the sub-mould region of continuous casting.

Modelling coupled flow and electromagnetic equations in three-dimensional eddy-current problems is a current and open area of research. This is largely due to the free boundary nature of Maxwell's equations and the subsequent difficulty of restricting the solution to the region of interest. CHAM's novel approach to solving the problem includes the following features:

- 3-Dimensional simulations
- Split simulation (the electromagnetic and flow simulations are uncoupled)
- Electric field (solved whilst the magnetic field is calculated)
- Coil implementation (external to the solution domain)
- Alternating current low frequency conditions
- Integral-differential approach to the EM solution (which limits the solution domain to the CFD domain)
- Steady-State time averaged solution of EM equations
- Steady-State flow solution
- Darcy type solidification model
- Thermal analysis and latent heat sources



Contours of solid fraction along the casting
Blue = Liquid Strand ; Red = Solid

Various levels of model complexity can be activated through the q1 input file such as a choice between a 1D approximation to the electric field calculation or a novel 3D alternative calculation.

The work provides a framework for the modelling of an electromagnetically driven continuous casting system. The open nature of the PHOENICS environment has been fully utilised and the electromagnetic physics has been integrated through GROUND coding.

The solution of these time harmonic electromagnetic equations is an exciting and new area of research for CHAM and is at the vanguard of current research.

Mick Hughes, Email: mh@cham.co.uk

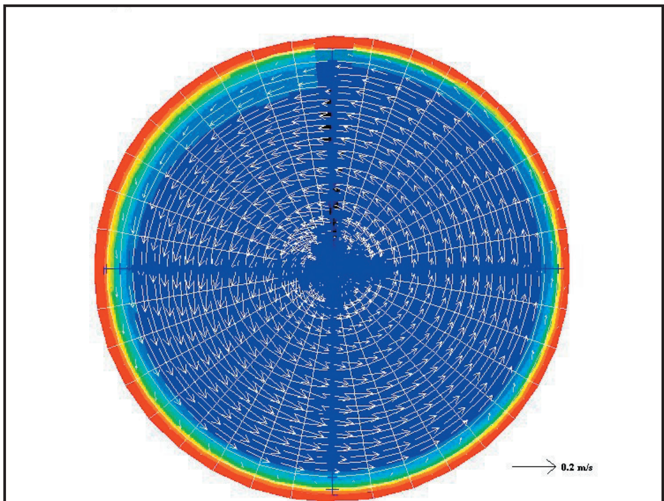
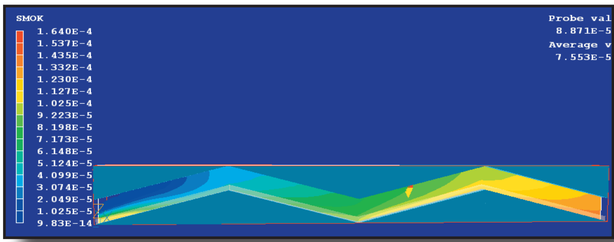


Figure shows velocity vectors plotted with solid frection.
- Note the rotational motion generated by the electromagnetic stirrers

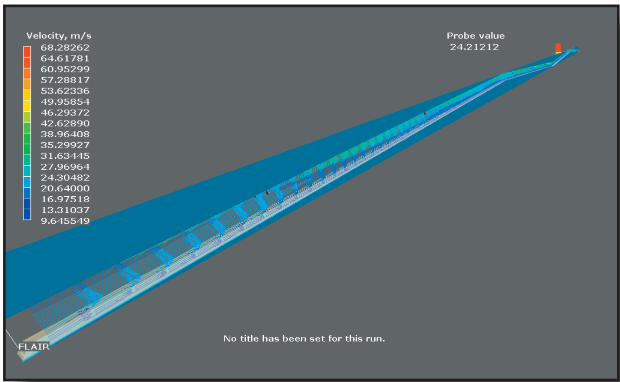
TO BFC OR NOT TO BFC? – THAT IS A QUESTION !

Ventilation of road- and rail-tunnels is commonly modelled using a Cartesian mesh in the VR environment. But what if the tunnel in question has curves or undulations as in the case posed by the Land Transport Authority of Singapore? Would BFC's be more appropriate?

Peter Spalding asked visiting student Mohuiddin Khaja to investigate both approaches in order to assess the pros and cons.



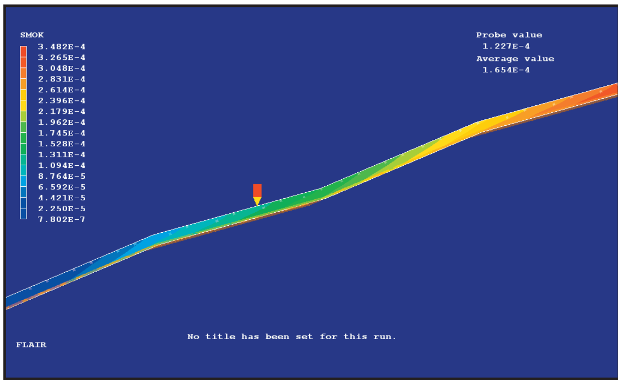
Concertinaed View – With Fans - Cartesian



Perspective View – With Fans – Cartesian

His conclusions?

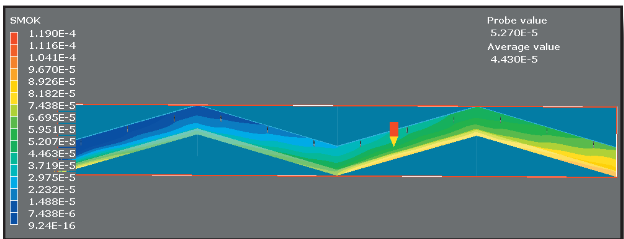
As one might expect, both the BFC and the Cartesian-mesh approaches produced very similar results. These showed an unacceptable build-up of carbon monoxide in the tunnel, with a commensurate increase in air temperature, towards the exit of the tunnel when operating without fan-assisted ventilation. With fans operating, the figures reduced to reasonable levels.



CO level – no fans – BFC's

The case involved a two-lane subterranean highway in Singapore, through which flowed 2000 vehicles travelling at 60Km/hour per hour; each vehicle releasing 0.1863m3/s with a heat load of 16KW. The purpose of the study was to establish the effectiveness of fans, spread down the length of the 1Km tunnel, on the heat and pollution levels created by the traffic.

Mohuiddin produced results for cases with and without fans and, as an exercise, used both Cartesian and Body-fitted meshes to take into consideration the +/- 3% incline in the tunnel itself.



Concertinaed View - CO levels - Cartesian

In terms of problem definition and solution, the methods varied dramatically. The set up time using BFC's, for a novice user, took over a day to create the model compared to less than half that using the built-in shapes within the VR library. Conversely, the run-times using a 3MHz PC varied from a few minutes using the BFC approach to up to 5 hours with Cartesian. The reason being, of course, that all the cells within the BFC case focussed on the flow domain, whilst the alternative method involved many more cells, many of which were situated in blocked areas.

Nevertheless, if one considers the cost of man-time versus computer time, and the ease-of-use and greater flexibility afforded by the Cartesian approach – perhaps this remains the better method.

Peter Spalding, Email: pls@cham.co.uk

GAS FREEING OF A VERY LARGE CRUDE CARRIER

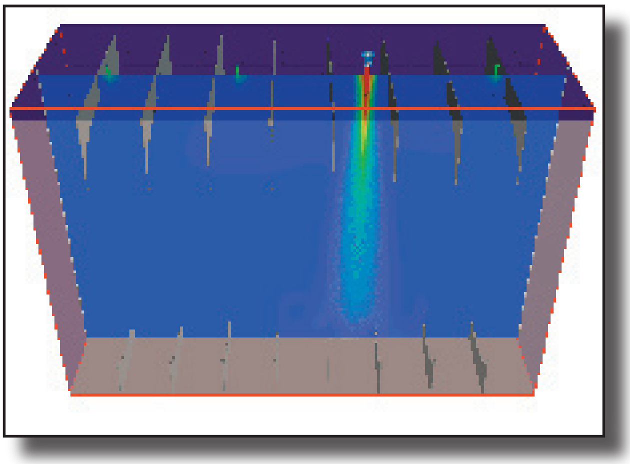
When an oil tanker's hold needs to be inspected, or hot work performed inside, gaseous vapours that originate from crude oil in the tank must be evacuated. Traditionally this involves the use of a de-gasification or "gas-freeing" fan with flow-rates upwards of 13,000 m3/h. The air is blown into the tank causing ventilation through mixing. However, when dealing with tank volumes upwards of 20,000m3, with heavy vapours that sink to the bottom of a heavily partitioned tank, the efficiency of the fan in removing the vapours from such a large tank is unknown.

PHOENICS was used to calculate and visualise the flow-field inside the tank to better understand the mechanisms that drive this kind of large-scale mixing ventilation. Incorporation of multiple gaseous phases is taken into account through the use of the algebraic slip model (ASM) so that accurate dispersion and entrainment of the different fractions is found.

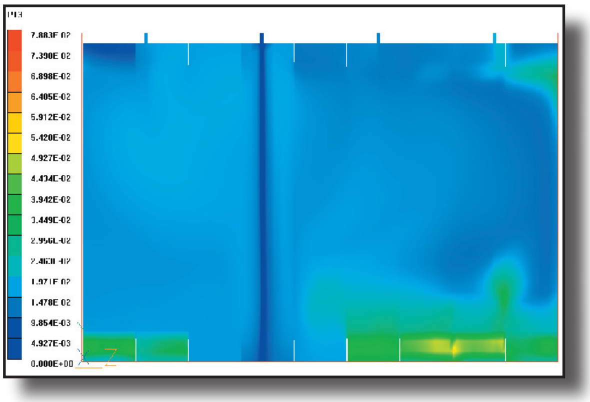
Current work aims to further the understanding of the complex gas flows inside the tank, with a view to examining just how well fan-driven gas freeing performs. Steady-state simulations run to date show a difficulty in removing heavy gas vapour from a partition far from the main air jet.

Future work is directed at examining the behaviour of the mixture of gases in the gas-freeing process; in particular, how the internal tank geometry affects the flow of air that entrains the noxious gases, with a view to optimising the process to decrease the time to gas-free the tank.

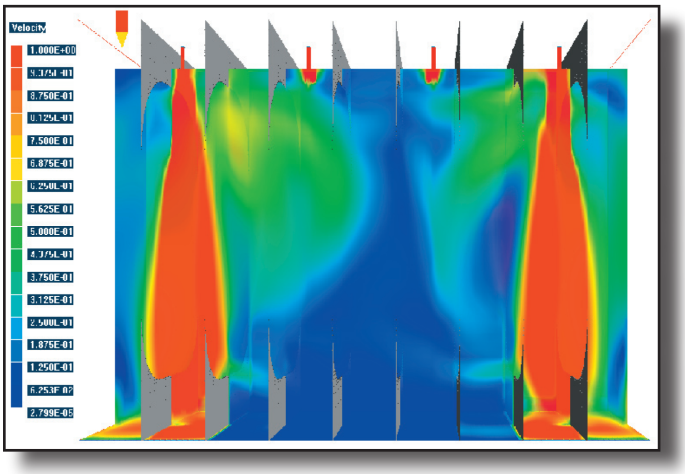
Kevin Chow Email: K.Chow@herts.ac.uk



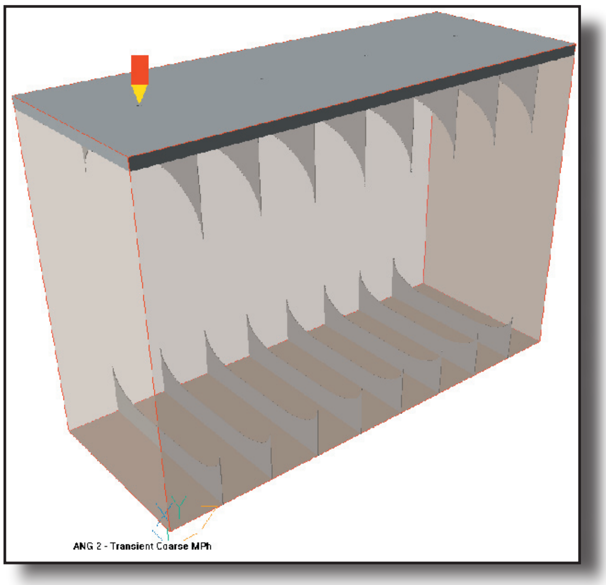
Another velocity field contour plot; note the size of the gas-freeing fan on the top to the dimensions of the tank. (Approximate size)



Concentration field of gas PT3 (ethane)



Velocity field contour plot (0-1m/s)

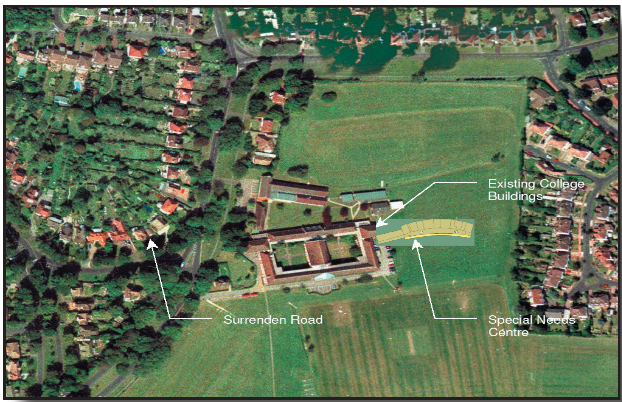


Internal Tank Geometry. The probe is pointing to one of the venting holes. (318mm diameter). Dimensions of the tank are 45x17 base area, 31m high.

SPECIAL-PURPOSE SOFTWARE FOR SPECIAL-NEEDS CENTRE

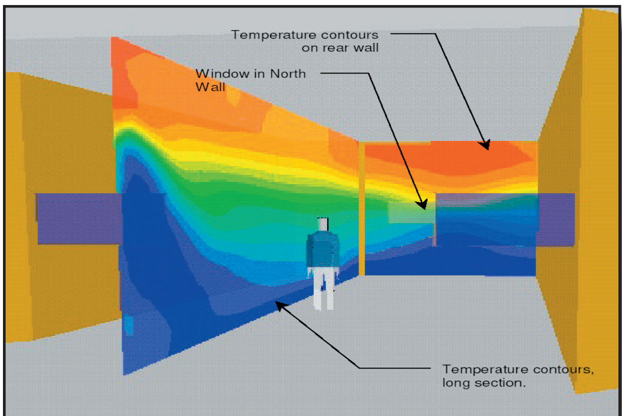
PHOENICS On-Line users, Silcock Dawson and Partners, were contracted by Varndean College in Brighton, Sussex, UK, to evaluate the proposed natural ventilation systems for a new Special-Needs Centre.

The PHOENICS special-purpose building services module, FLAIR, was used to model the detailed arrangement of the ventilation openings throughout the development.



It was necessary that the CFD model should provide an indication of the temperature inside the rooms relative to the external temperature as well as predicting the airflow through the rooms.

In order to simplify the model and provide sufficient resolution inside the building an external model was built to predict the wind pressure at the building facades, then further models of the rooms were built to the necessary degree of detail. The wind pressure data from the external model was then used to allow the room models to predict the airflow rate through the windows.



The analysis helped the architect to specify the size and number of roof cowls and opening windows that would be required for adequate ventilation throughout the development.

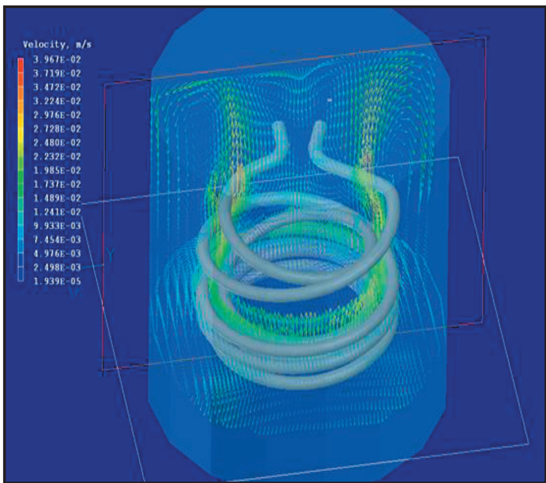
It was also found that ventilation specified for the atrium would successfully control the temperature in the occupied zone to less than 1.5°C above the ambient temperature. Under light wind conditions, 2m/s, the atrium will have an air change rate of approximately 20 with all windows and roof terminals open.

Web: www.silcockdawson.co.uk

GETTING INTO HOT WATER?

Heatrae Sadia, the UK's leading manufacturer of hot water products, posed a straightforward evaluation problem to several well-known CFD vendors. Given certain criteria, how long does it take to raise water temperature to 45°C?

The case was, of course, transient involving a cylindrical tank, complex internal geometry, with heat transfer. So we used a Cartesian mesh, together with the IMMERSOL radiation model and the PARSOL partial solid feature – were we mad?

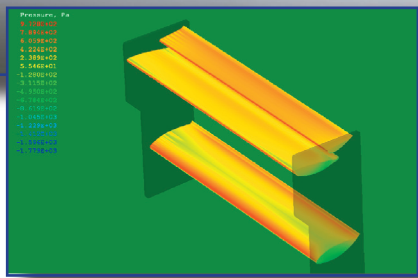


Velocity vectors coloured by temperature during tank heat up

Not a problem for PHOENICS-3.6.0, which produced results nicely in line with experimental data, and reached a conclusion before codes using alternative meshing techniques.

www.heatraesadia.com

PORSCHE 911 GT3 AIRFOIL MODEL



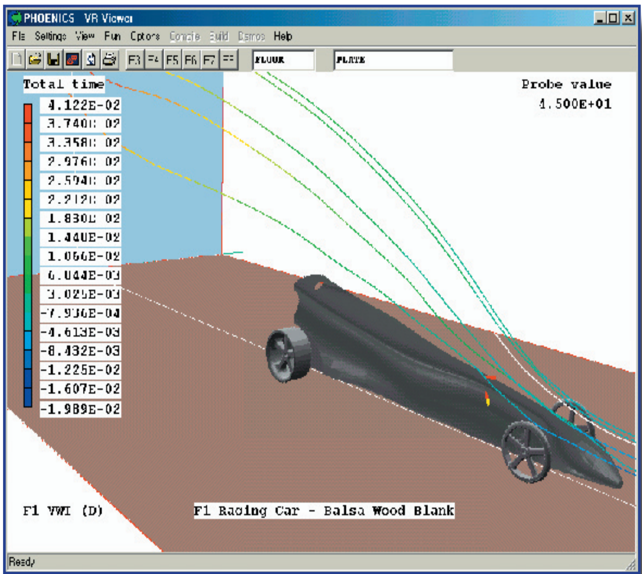
CHAM is working in collaboration with Staffordshire University and James Watt Automotive on a project to re-design the rear wing of a Porsche 911GT3 LM specification endurance car.

The LM endurance series is run at major tracks in Europe such as Spa, Monza and Silverstone. The objective of the project is to increase the available down force without compromising drag.

Contact David Cottrell - Email: dc@cham.co.uk for further details about progress on this project.

F1 IN SCHOOLS PROGRAMME

The “F1 Virtual Wind Tunnel” sub-set of PHOENICS is now in widespread use by schools and colleges competing in the F1-in- Schools Challenge. The software is in use by over two hundred schools here in the UK, with an ever-increasing user base worldwide.



The first international final took place in October 2004. BETT2005, held at Olympia, London in January this year, hosted the finals of the UK Schools contest. The winning team from St John’s Roman Catholic High School in Dundee was presented with a new Mk3 version of F1 VWT. This version incorporates the new rules and regulations associated with the new ‘R’ class model, as well as improved post-processing graphical options.

Mk3, which uses PHOENICS-3.6 as its basis, will be updated once again during 2005, to include further changes needed for the rules and regulations introduced for the new Apprentice Class outlined in the Jaguar F1 in Schools Challenge Pack.

DENFORD

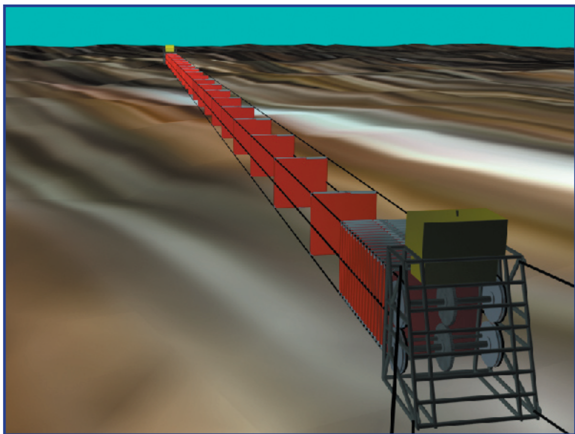
www.denford.co.uk/f1inschools.htm

TIDAL POWER STATION TO SURPASS THE REST

The University of Hertfordshire is performing an optimisation of an underwater “sail” concept using PHOENICS-based CFD modelling for a new tidal power station, designed by Tidal Sails AS from Norway, which, it is claimed, will be more efficient than any existing schemes.

The power station (shown in the conceptual figure) will consist of large underwater sails that capture energy from tidal currents and transfer it to electricity generators. Fluid mechanics will play an important role in the design of the concept and a number of fundamental simulations will be carried out using PHOENICS.

Arne Hōldo, Email: a.e.holdo@herts.ac.uk



Picture courtesy of Tidal Sails

KEEPING A SCHOOL COOL

School elevation - architect Scott Brownrrigg

Children at the new Ruislip High School to be built by the London Borough of Hillingdon are set to benefit from an innovative low-energy solution to the problem of keeping classrooms cool in summer, whilst sealing the external envelope.

In a typical classroom with 32 pupils, the heat gain from people, computers, lighting and sunshine can be as much as 6.5 kW. The school is close to an elevated railway and to Northolt and Heathrow airports, and the high external acoustic levels dictate that the windows have to remain closed.

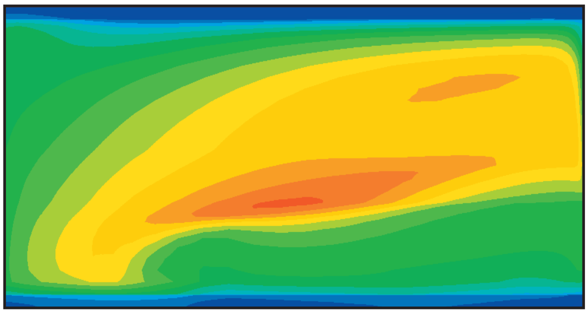
Due to sustainability aspects and project cost constraints, the normal option of mechanical cooling was not feasible, and consultants Scott Wilson decided to adopt the innovative approach of "passive slab pre-cooling". This requires the usually concealed underside of the concrete floor slabs to be left exposed and for the upper pane of each classroom window to be opened at night to admit cool air that instils "coolth" into the slab.

Air movement through the classrooms is achieved by inserting acoustic transfer grilles in the walls between each classroom and the adjacent corridor / atrium space, together with extract fans located in the upper part of the building. To ensure adequate ventilation rates are achieved in the daytime, the fans operate at a reduced duty and induce "trickle ventilation" via acoustic ventilation units located beneath each classroom window.

Scott Wilson commissioned Flowsolve Consultants to simulate the airflow in a typical classroom, to assess whether or not passive pre-cooling would be a viable solution. Transient simulations using PHOENICS with a one-hour time step were continued for seven days and nights, by which time the temperatures settle into a periodic daily pattern. The CFD model shows that, provided an adequate flow rate is maintained during the night, the reservoir of "coolth" stored within the concrete floor slabs achieves a reduction in peak daytime classroom temperature of 6°C for a typical day in early summer.

Without using mechanical cooling, the results satisfy the Building Bulletin Guide requirement that classroom temperatures should not exceed 28°C for more than 40 hours in a year

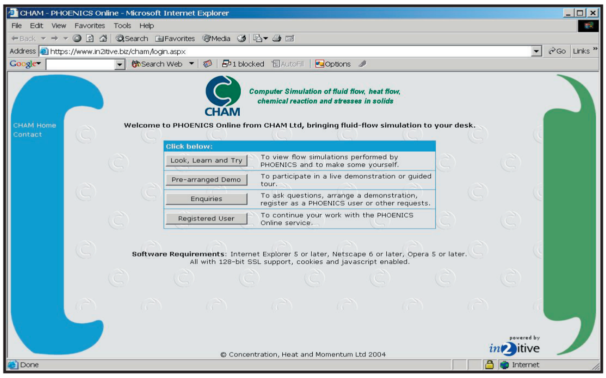
David Glynn, Flowsolve
Email: cfd@flowsolve.com



Temperatures on room cross-section - air cools as it flows along the ceiling from right to left, then falls

PHOENICS – ONLY A CLICK AWAY

The PHOENICS On-Line service provides low-cost interactive access to both PHOENICS-3.5.1 and PHOENICS-3.6.0 via the Internet. The customer base has increased quite dramatically during 2004, incorporating users from as far away as Chile and China – no distance at all for the Internet. We look forward to further expansion during 2005.



The service remains particularly attractive to customers wishing to make infrequent or project-based use of the code, and for those wishing to gain access from multiple locations.

Participants at UK training courses enjoy two months free access to PHOENICS On-Line thereafter.

Click on www.in2itive.biz/cham to try out the free-to-access Look Learn Try facility, or email: sales@cham.co.uk to arrange an on-line demonstration or a free trial evaluation.

NEWS AND EVENTS

Benelux User Meeting

Venue: ARISTO Eindhoven
Date: 24th May 2005
Host: CHAM / A2TE
Contact: Geert Janssen
Tel: +31 40 653 2569 33
Email: gjanssen@a2te.nl.com

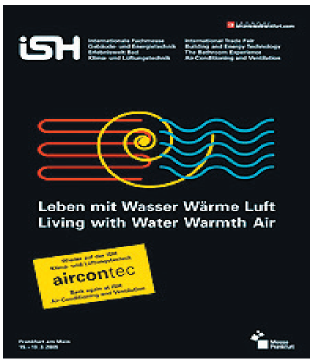
UK User Meeting

Venue: CHAM, London
Date: 17th May 2005
Host By: CHAM
Contact: Peter Spalding
Tel: +44 (0)20 8947 7651
Fax: +44 (0)20 8879 3497
Email: pls@cham.co.uk

SIA International Congress

Venue: SIA, Lyon
Date: 26th – 27th Oct 2005
Host: Société des Ingénieurs de l'Automobile
Contact: Marc Charlet
Tel: +33 1 41 44 93 75
Fax: +33 1 41 44 93 79
Email: marc.charlet@sia.fr

During March 2005, Dynamics Modelling Ltd showcased PHOENICS in conjunction with Wolter Fans (UK) at the ISH show in Frankfurt, Germany.



http://ish.messefrankfurt.com/frankfurt/en/home.html

PHOENICS Training Courses

Venue /Dates:
CHAM 12 to 14th April 2005
CHAM 14th to 16th June 2005
CHAM 20th to 22nd Sept 2005
CHAM 15th to 17th Nov 2005
Contact Peter Spalding
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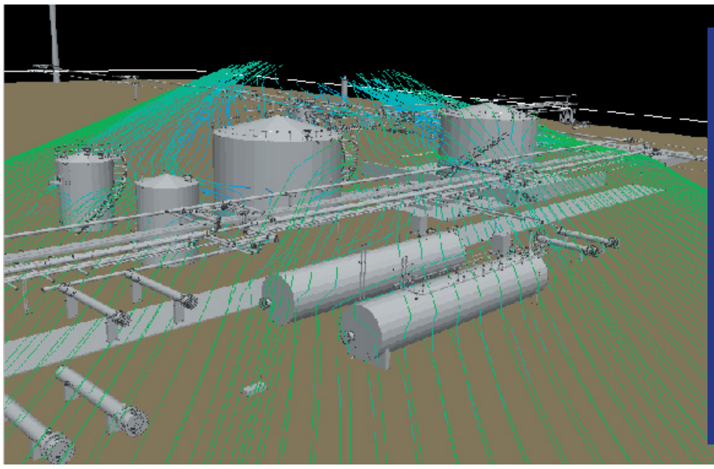

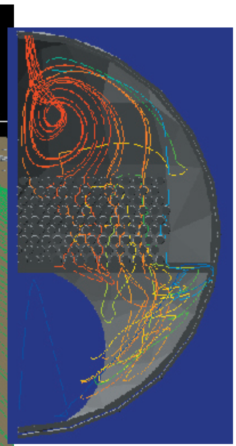

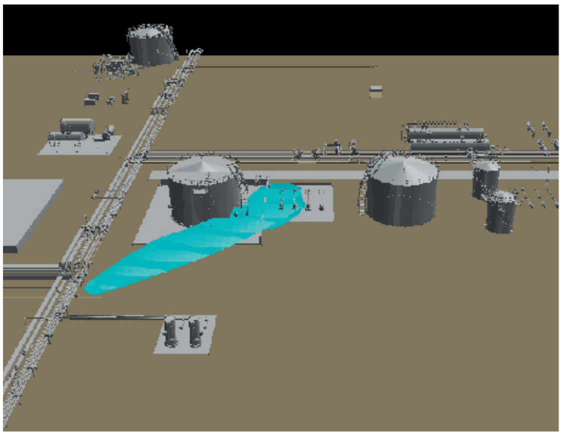

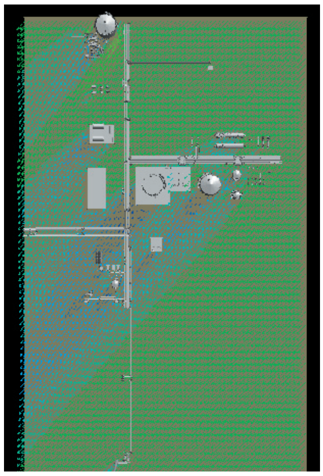

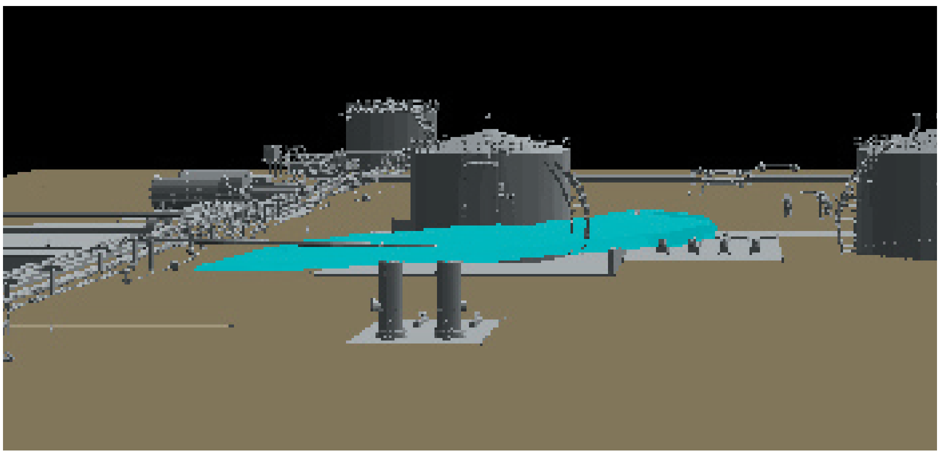

Pictures courtesy of CHEMTECH, Brazil

Designed and compiled by Peter Spalding
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