What's New in PHOENICS-2022

CHAM

Experts in CFD Software and Consultancy

PHOENICS-2022

If it flows, PHOENICS can model it

PHOENICS has been extensively validated across many areas of environmental, engineering, and other CFD applications, over time, and worldwide.

PHOENICS is an easy-to-use tool which will help you simulate, test, improve, and optimize product performance without expensive real-time tests. Let the code's reliable and extensive physics create the models you need for all applications involving fluid flow.

Or, if you prefer, our skilled technical team will undertake the work for you?

Brian Spalding, founding father of commercial CFD, created PHOENICS with his team. Members of that team, with years of CFD expertise and experience, keep PHOENICS updated and relevant.

See inside for new features, changes, updates and bug fixes in PHOENICS-2022; and for work in progress.

PHOENICS-2022 will be available to current Users who update under annual maintenance agreements. New PHOENICS Users will receive the version automatically.

If you do not, yet, use PHOENICS why not try

PHOENICS- on-the-Cloud?

This is an increasingly popular, cost-effective, way to run large cases on the powerful multi-core systems offered by the Microsoft Azure marketplace. Access is available via www.cham.co.uk or sales@cham.co.uk or ring 020 8947 7651 for assistance.

Colleen Spalding, Managing Director

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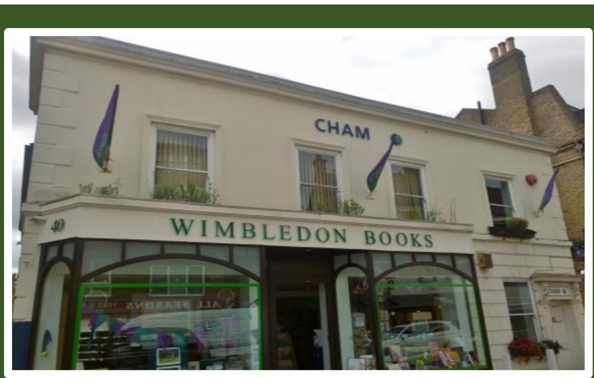
PHOENICS-2022 Features

1) ***Three-Phase Volume of Fluid (VOF)***
2) ***Non-Newtonian Models: Extended Range***
3) ***Wind Farms: Unstructured Terrain Model***
4) ***FLAIR: PET & TSI Indices, Terrain Object***
5) ***Sutherland's Law of Thermal Conductivity***
6) ***IPSA: Particle-Cluster 4-zone Fluidisation Drag Model***
7) ***Bug Fixes***
8) ***Work In Progress***



1) 3-Phase Volume of Fluid (VOF)

VOF is a free-surface modelling technique, which solves a conservation equation for the volume fraction of a heavy fluid using specialised techniques to preserve a very sharp interface.

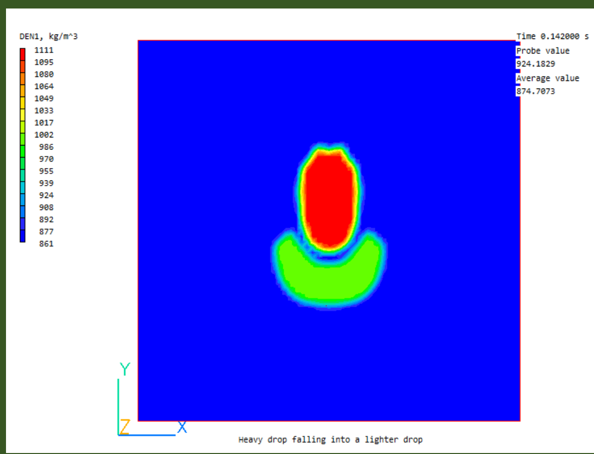
VOF facilities in PHOENICS have been extended over the years to include THINC_WLIC (Tangent of Hyperbola for Interface Capturing, Weighted Line interface Calculation) CICSAM, HRIC, etc.

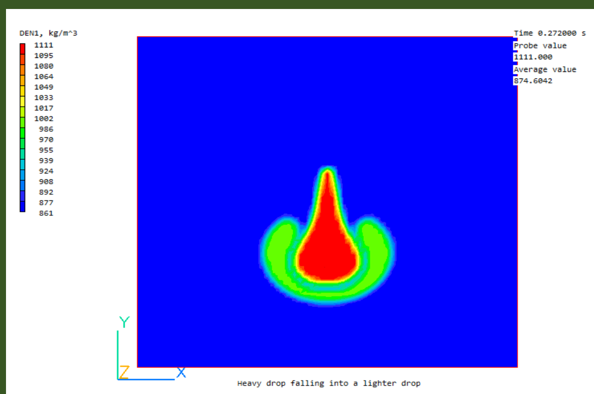
3-Phase VOF is the latest addition. It allows for 3 distinct phases by solving an additional conservation equation.

Allowed combinations are:

1) Gas / liquid / gas,
2) Liquid / gas / liquid,
3) Liquid / liquid / liquid or gas / gas / gas.

The surface contact angle calculation is also improved.





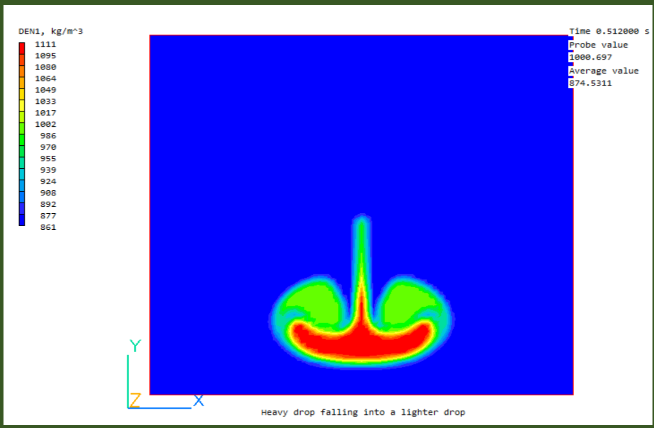
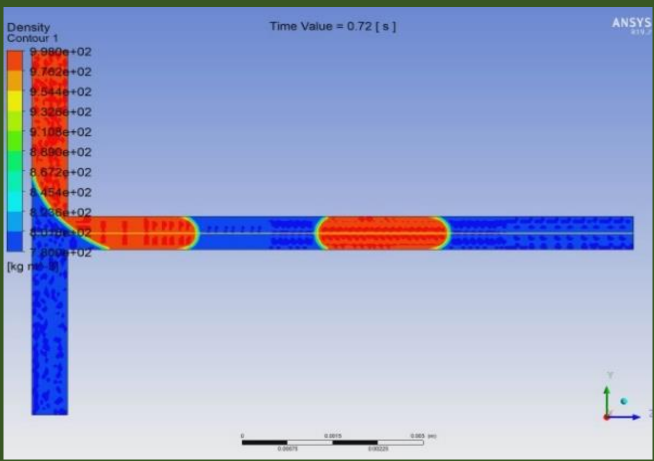
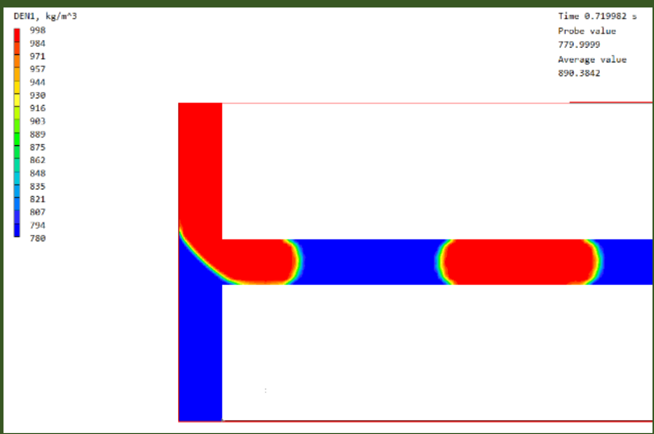


Figure: A heavy drop falling into a lighter one

Comparisons with Ansys™ were made for water / kerosene slug flow. Comparative results were excellent - as can be seen below.





All PHOENICS VOF models can handle temperature-dependent cases, with proper treatment of temperature in each phase and in any immersed solids.

Added options make surface tension a linear function of temperature, or use the Langmuir equation of state which includes a scalar as well as temperature. A constant static contact angle can be specified to model wall adhesion effects.

2) Non-Newtonian fluid Models

PHOENICS may now contain more built-in options to model viscous non-Newtonian fluids than *any* other CFD code.

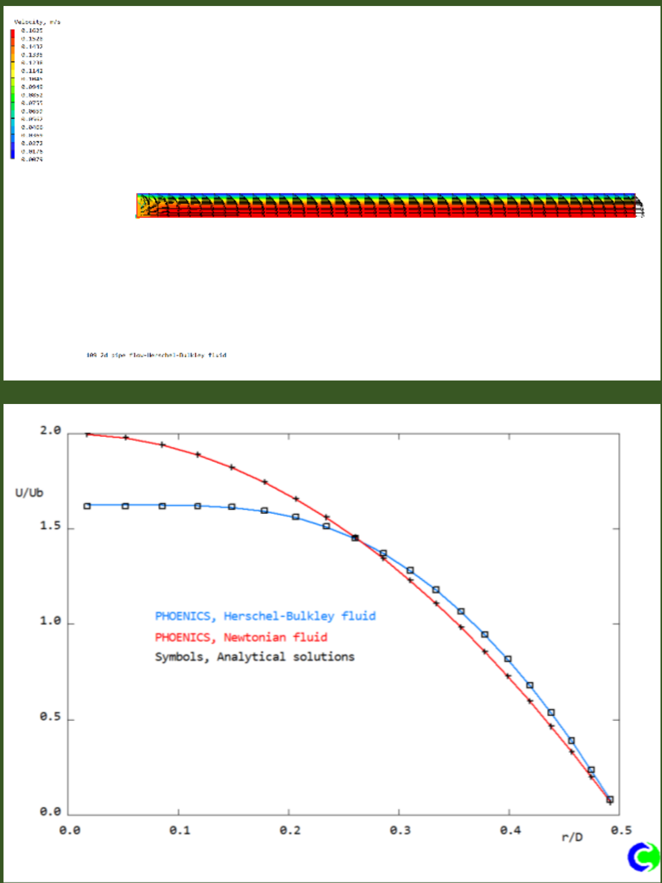
Seven, additional, non-Newtonian models are coded into PHOENICS-2022. It is equipped with a wide range of menu-driven models including standard versions of: Power-law, Sisko, Cross, Carreau, Carreau-Yusada, Powell-Eyring, Bingham Plastic, Herschel Bulkley,

The models are documented in POLIS and validated via library cases for tube flow. Some optional functions have been provided, documented, and tested for temperature-dependent rheology including the use of Arrhenius-type exponential functions.

PHOENICS results for all fluid types compared successfully with analytical and/or numerical solutions, including those for the Graetz problem for heat transfer to a polymer melt with viscous dissipation at high Brinkman number.

PHOENICS is upgraded to include the Papanastasiou regularisation for viscoplastic fluids, which improves convergence rate when simulating the flow of these fluids, especially at high Hedstrom/Yield numbers.

Non-Newtonian PHOENICS features will successfully, and reliably, model fluids including blood, clay, food (ketchup, salt solutions, custard, corn starch, melted butter), grease, mud, polymers, toothpaste, shampoo, paint, sewage sludge, and slurries - **and more.**



Laminar Pipe flow at Reynolds number=10: It can be seen that the shear-thinning effect of a Pseudoplastic non-Newtonian fluid produces a very flat velocity profile in the core of the flow.

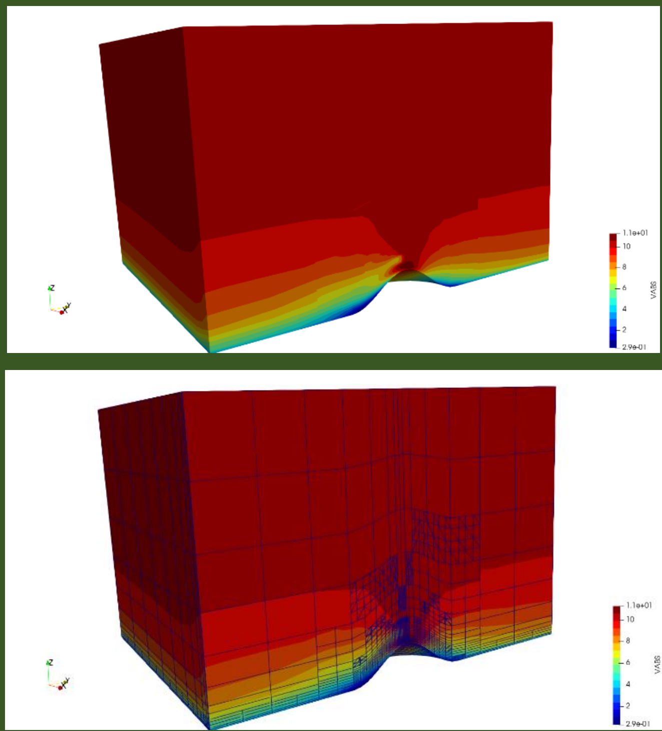
3) USP - BFC Unstructured Terrain Model for Wind Farms

PHOENICS powers WindSim the "wind farm design software based on CFD (Computational Fluid Dynamics)" used by a Company of the same name in Norway. CHAM has supplied PHOENICS to WindSim (founded as Vector AS) for Wind-Farm use since the mid-1990s.

In the latest cooperative venture, a USP version of PHOENICS was created, by CHAM, for WindSim using a terrain-following BFC (Body-Fitted-Coordinate) grid as the unstructured mesh starting point.

It is expected that this product will be available in a future release of WindSim. It is not, initially, presented as a stand-alone PHOENICS option.

Use of local grid refinement allows total cell numbers to be greatly reduced compared to the traditional structured BFC mesh. The code can be run in parallel.



Flow over a Cosine Hill with Turbine and local refinement

The resulting grid can incorporate local refinements near ground plane and around wind turbines. These are represented as actuator discs using InForm - which is a supplement to the PHOENICS Input Language (PIL) facilitating input of problem-defining data. It allows users to express requirements through algebraic formulae for:

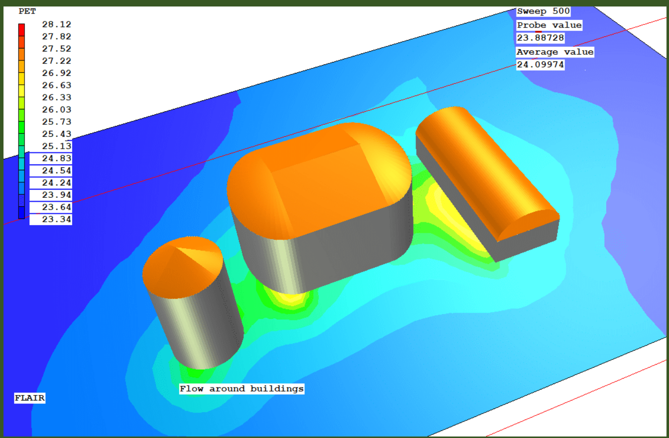
- space and time discretization,
- material properties,
- initial values,
- sources,
- boundary conditions,
- body shapes and motions, or
- special print-out features.

4) FLAIR

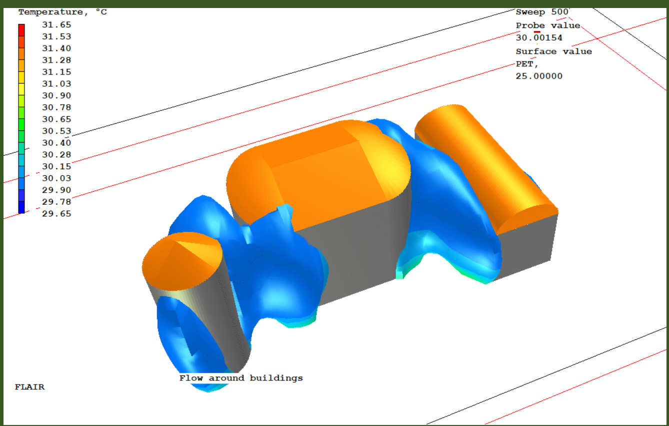
4.1 PET Comfort Index in FLAIR

PET (**P**hysiological **E**quivalent **T**emperature) is a thermal comfort index based on a prognostic model of the human energy balance that computes skin and body core temperature, sweat rate and, as an auxiliary variable, clothing temperature.

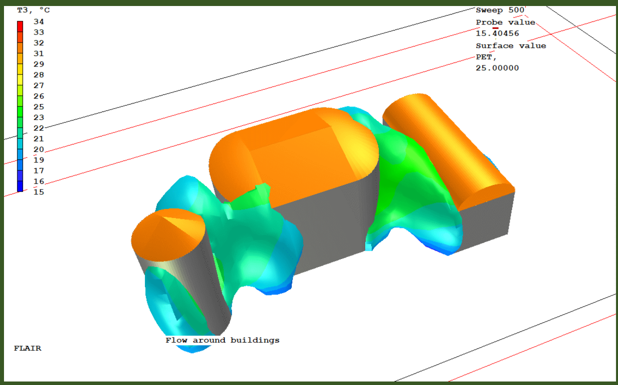
PET is based on the Munich Energy-balance Model for Individuals (MEMI) and used to model impact of heat, wind, etc on the body to create a comfortable human environment. Images below show PET contours.



Flow around a group of buildings



Iso-surfaces of PET 25° coloured by air temperature



Radiant temperature

4.2 Thermal Sensation Index in FLAIR

TSI (Thermal Sensation Index) is an empirical model which considers five climatic factors - air temperature, horizontal solar radiation, wind speed, relative humidity and mean radiant temperature - at a given location and time.

It is the index that public housing projects in Hong Kong adopt; its prevalence there can, perhaps, be explained by its user-friendly nature. CHAM has implemented a simplified version according to BEAM Plus New Buildings Version 2.0.

4.3 Terrain Object for FLAIR

A new class of object – TERRAIN – has been introduced for FLAIR. The aim is to simplify the settings required for external wind-driven flows.

The TERRAIN object makes the correct settings by default, and where possible offers to copy ground boundary-condition settings from the WIND object so that Users do not have to set the wall roughness for objects representing buildings and/or the ground. The

4.4 Foliage Object

A default drag coefficient for 'small plants' has been added to the list.

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5) Sutherland's Law of Thermal Conductivity

Practical engineering can posit problems involving noticeable temperature changes in the flow field which require a model for both thermal conductivity and viscosity.

PHOENICS already provides Sutherland's law for gases; it now contains an additional option for calculating the temperature-dependent thermal conductivity of a gas.

Values of constants for several common gases are included. The law is based on an idealized intermolecular-force potential and is given by:

$$\mu = \mu_o \frac{T_o + C}{T + C} \left(\frac{T}{T_o} \right)^{3/2}$$

6) IPSA (Inter-Phase-Slip Algorithm)

Spalding developed IPSA (see *Royal Society Memoir extract below*). It entails solving full Navier-Stokes equations for each phase and has been available in, used by, and built into, PHOENICS since ***1981***.

"After developing a satisfactory calculation method for single-phase problems, Spalding turned his attention to multi-phase flows, for which he proposed the inter-phase-slip algorithm (IPSA), in which each phase is assumed to form a continuum, interpenetrating other phases. At each location, each phase has a volume fraction and its own velocity and temperature field. The transport equations for each phase contain terms representing inter-phase transfers.

Thus, any velocity difference (the slip) between other phases creates a shear-force term, while temperature differences lead to inter-phase heat transfer." (https://royalsocietypublishing.org/doi/10.1098/rsbm.2018.0024).

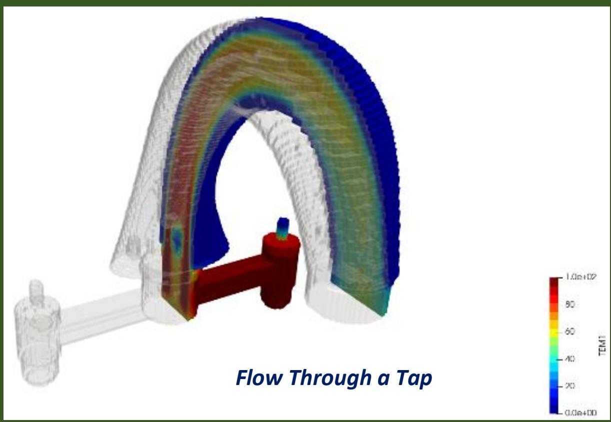
PHOENICS-2022 contains a new IPSA capability namely a *particle-cluster 4-zone fluidisation drag model* which is included for fluidised bed applications and characterised by four different flow regimes, namely: dense, sub-dense, sub-dilute and dilute. A blending function is introduced to provide smooth transition between the various regimes.

7) Bug Fixes

- Area source applied by volume object.
- VABS calculation next to blockage one cell ahead corrected.
- IMB1 is now mass error regardless of CONWIZ=T?F. Previously this was volume error for CONWIZ=T, mass error for CONWI=F.
- IPSA phase-diffusion flux for SPARSOL corrected.
- SUN object when #QS2 not STOREd corrected.
- Pressure and friction integration corrected.
- THINPLT in parallel, to allow object to be on edge of sub-domain corrected.
- New PBP solver in parallel corrected.
- Object detection in polar when part of object lies outside domain corrected.
- Detection of cut cells for VOF regardless which fluid is domain fluid allowed (rather than detection only if domain fluid was 'heavy').
- Potential out-of-bounds array error when sorting intersections along a gridline for SPARSOL avoided,
- 'PERSON' object corrected in 'user' posture to prevent unexpected size/position changes.
- When changing CELLTYPE to USER_DEFINED, flag is set so object does not affect the grid.
- Display of probe location / value when domain origin is offset from zero – also affects probe value extraction using macro corrected.
- Polar geometry files polhalfcylinder.dat and polquatercylinder.dat corrected.
- Emissivity of 198 blockage disappearance corrected.

8) Work in Progress

8.1 Unstructured PHOENICS (USP)



Flow Through a Tap

USP means PHOENICS does not always need a structured grid leading to advantages of computational economy. Unstructured grid cells employed remain predominantly six-sided and, except where obliquely cut by surfaces of physical objects, of cartesian or cylindrical-polar shape. The faces may have unequal cell numbers on opposite sides; usually one on one side and two/four on the other.

One source of economy is the use, in effect, of different grids for different variables. If solids and fluids are in the same domain, cells in the solid part are used only for temperature, because no pressures, velocities (or other scalars) are computed there.

Unstructured/structured PHOENICS exist simultaneously in one executable and have much in common.
Points of similarity include:

- Problem-set-up data are supplied via a q1 file to Satellite and via an eardat file to EARTH;
- Calculation outputs appear in RESULT / PHI files;
- Graphical output to monitors appears similar.

Points of difference include:

- USP requires additional instructions from users regarding the grid to be used.
- Data formats written to RESULT / PHI files differ.

PHOENICS-2022 UnStructured (USP) includes:

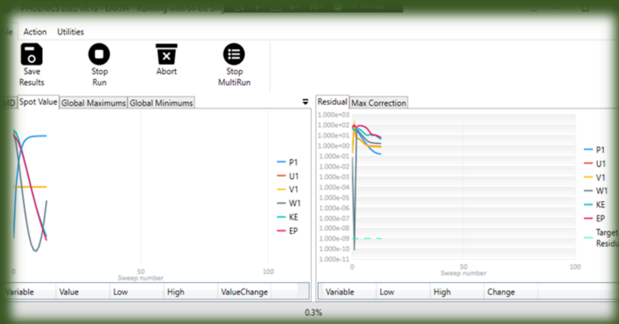
- USP mesh display in VRE; USP solutions in VRV.
- Allowance for parallel operation
- Additional models and comfort indices.

8.2 Volume of Fluid (VOF)

A steady-state extension for suitable cases is planned.

8.3 Earth Convergence Monitor Update

The Earth convergence monitor screen (GXMONI) is being replaced by a more modern, flexible, layout which will allow any combination of available monitor graphs to be shown in a single window (as now) or on split screens in appropriate windows.



8.4 IPSA Extension to include KTGF

KTGF (Kinetic Theory of Granular Flow) allows particle-particle interactions by implementing several models for the solid stress tensor all based on this type of flow.

KTGF involves solving an equation for the granular temperature which represents the kinetic energy of the fluctuating particle velocity field.

The IPSA-KTGF model extends the capability of PHOENICS to handle, more realistically, solid-fluid applications like dense-regime pneumatic lines, riser reactors, and fluidised-bed reactors.

8.5 Bug Fixes

- Speedup of VRE/VRV by reducing the number of times the image is internally generated before being shown on the screen
- Dealing with occasional strange artefacts with shadows.
- IPSA divergence correction when R1 & R2 are both solved whole-field (as required by Hypre solvers).

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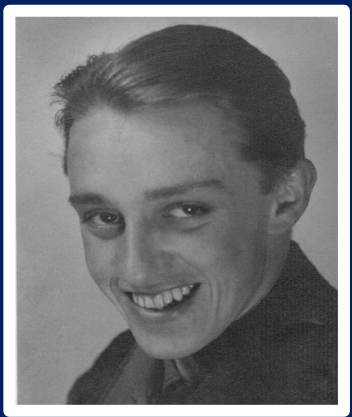
Brian Spalding FRS FREng ***January 09 2023 will be Brian's Centenary.***

It would have been marked by a Conference, a Journal article, mention in scientific publications, parties and gatherings. He would have enjoyed the Conferences, lectures, and articles more than the parties.



CHAM will dedicate the Winter Edition of the PHOENICS Newsletter to Brian. We hope to collect, and publish, memories provided by:

Those who knew him in any capacity (scientific, family, personal, academic).
Those who did not know him personally but knew of him through his work or other reasons.
Any who want to make a contribution.

This will be a memorial to a man who was a scientist, an academic, a mentor, a free thinker, a father of CFD, a poet, an intellectual.

Brian was multi-faceted - did you meet him at a Conference, was he your PhD supervisor, did you meet him on his, or your, travels, were you a colleague, have you read his books, articles or poetry, did you perhaps not meet him but have been influenced by his work or his actions – ANY connexion is relevant.

Contributions can be what their authors choose. They can, of course, be scientific but they do not need to be.

Articles do not have to be long – a sentence, a paragraph, a picture with a caption, anything which paints a portrait of someone who made a major contribution across so many aspects of life for 70 years or more.

For the Newsletter to be issued in January it is necessary to receive material as quickly as possible. If you would not mind, please send your memories to: newsletter@cham.co.uk

or by surface mail to:

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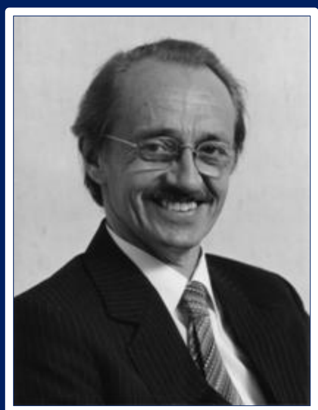

If you have photos of Brian - with you, in a group, anywhere, - please include them. If you have tapes, CDs, videos or anything showing him speaking whether it be a lecture or at a dinner, that would be excellent.

If you have recordings of his voice which could be shared they would be welcome.