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 models you need for applications involving fluid flow - or let us undertake the work for you.

Brian Spalding, founding father of commercial CFD, created PHOENICS with his team and updated it through his life. Members of that team, who worked with him on its creation and since, have years of CFD expertise and experience.

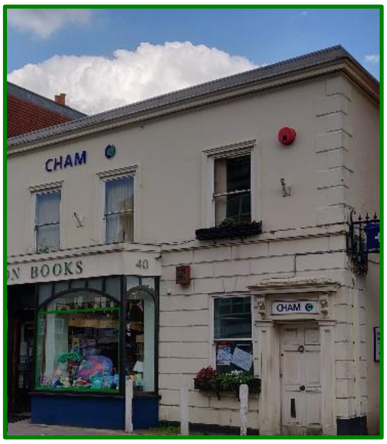
They use this expertise to keep PHOENICS up-to-date and relevant. See inside for new features, changes, updates and bug fixes in PHOENICS-2022.

If you do not use PHOENICS why not try it via PHOENICS on the Cloud? This route is increasing in popularity as a cost-effective way to run large cases on the powerful multi-core systems offered by the Microsoft Azure marketplace. Go to www.cham.co.uk or sales@cham.co.uk for help.

If you do use PHOENICS, V2022 is available when you update under your annual maintenance-agreement terms. New PHOENICS Users will receive this version automatically.

Colleen Spalding, Managing Director

Concentration, Heat and Momentum Limited (CHAM)
Bakery House, 40 High Street, Wimbledon Village, London, SW19 5AU, England
Tel: +44 (0)20 8947 7651 Email: phoenics@cham.co.uk Web: www.cham.co.uk



PHOENICS-2022 contains:

1) ***VOF: extension allowing for 3 phases***
2) ***Non-Newtonian Models: Extended Range***
3) ***Wind Farms: Unstructured Terrain Model***
4) ***IPSA: Extended to include Kinetic Theory of Granular Flow & Particle-Cluster 4-zone fluidisation drag Models***
5) ***Unstructured PHOENICS (USP)***
6) ***Sutherland's Law of Thermal Conductivity***
7) ***FLAIR: PET comfort indices included***
8) ***Double-Cut PARSOL/IMMERSOL: Extended***
9) ***Viscous heating source printing***
10) ***Bug Fixes***

1) 3-PHASE Volume of Fluid (VOF)

VOF is a free-surface modelling technique, which solves a conservation equation for the volume fraction of the 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 and allows for 3 distinct phases by solving an additional conservation equation. The allowed combinations are:
1) gas/liquid/gas,
2) liquid/gas/liquid,
3) liquid/liquid/liquid or gas/gas/gas.

The surface contact angle calculation has been improved.

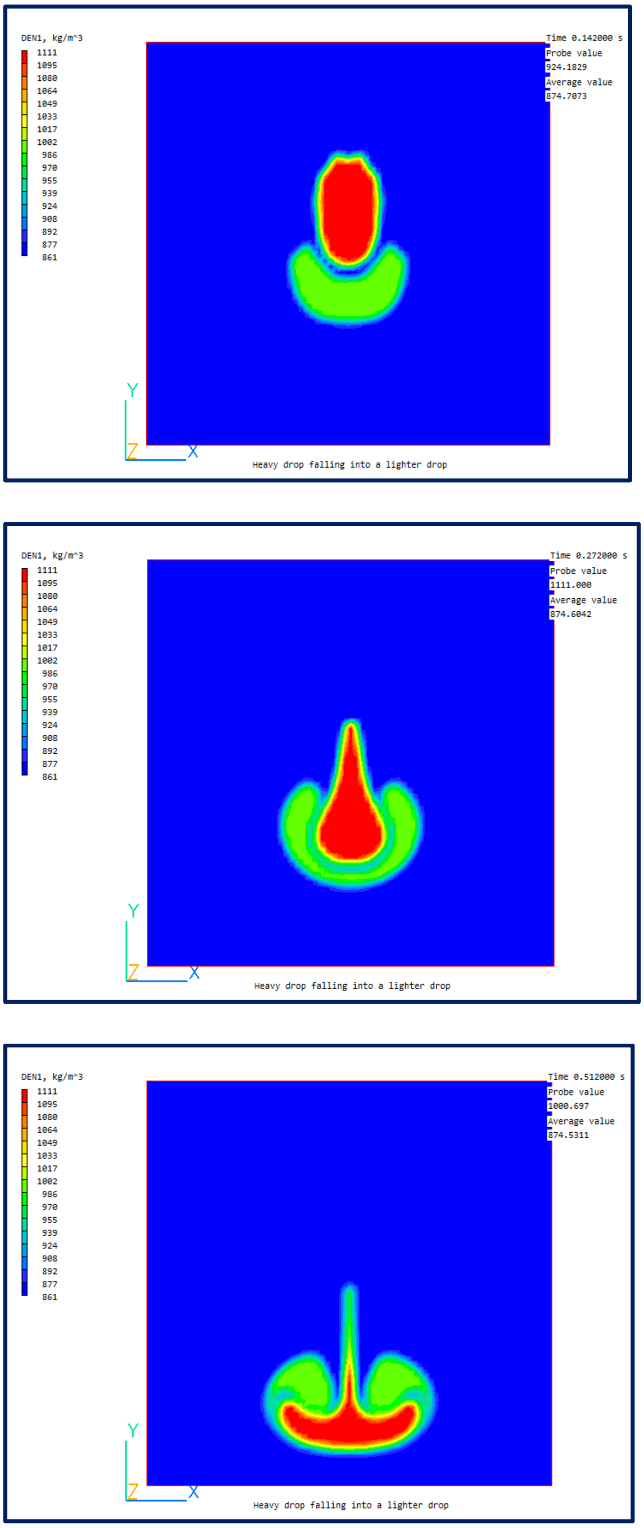
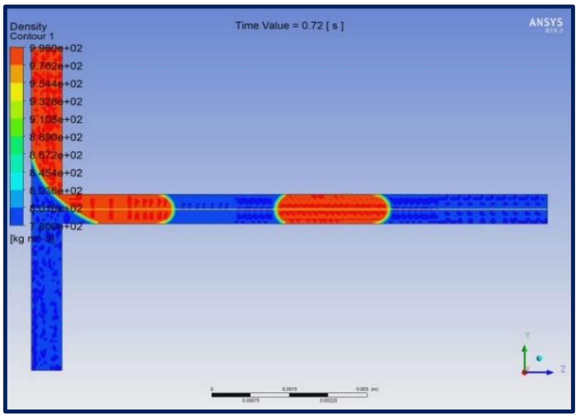
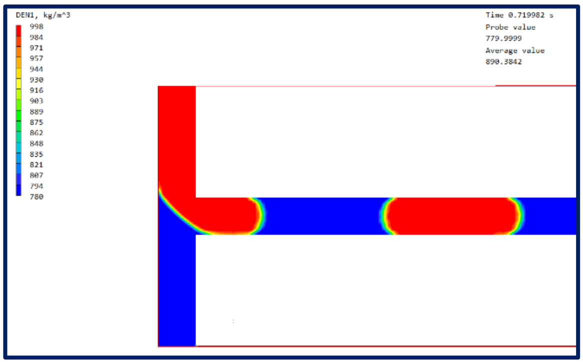


Figure: A heavy drop falling into a lighter one:

Comparisons with Ansys™ were made for water / kerosene slug flow. The 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

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, Casson and Ellis. These features facilitate simulation of an extensive range of fluids including blood, clay, foods, greases, mud, polymers, sewage sludge, and slurries.

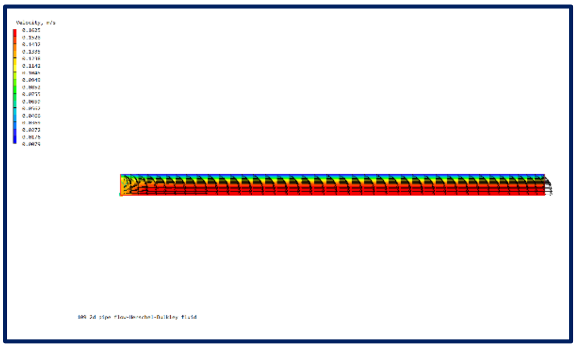
The models are documented in POLIS and validated via library cases for tube flow. Some optional functions have been provided, documented, and tested for temperature-dependent rheology including the use of Arrhenius-type exponential functions.

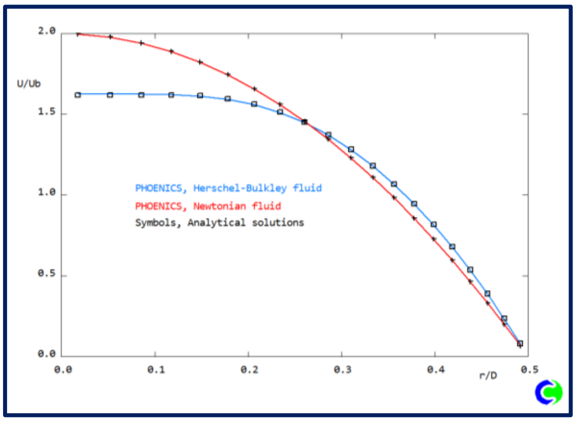
PHOENICS results for all fluid types compared successfully with analytical and/or numerical solutions, including those for the Graetz problem for heat transfer to a polymer melt with viscous dissipation at high Brinkman number.

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

PHOENICS may now contain more built-in options to model viscous non-Newtonian fluids than any other CFD code. It can reliably be used to simulate, for example, flow of blood (it does not follow Newton's law of viscosity, ie constant viscosity independent of stress). If modelling blood is of interest please get in touch.

The feature can be used to model, say, ketchup, which becomes runnier when shaken and is thus non-Newtonian. Many salt solutions and molten polymers are non-Newtonian, as are commonly found substances such as custard, toothpaste, starch suspensions, corn starch, paint, melted butter, and shampoo. PHOENICS can successfully model all of these and more.



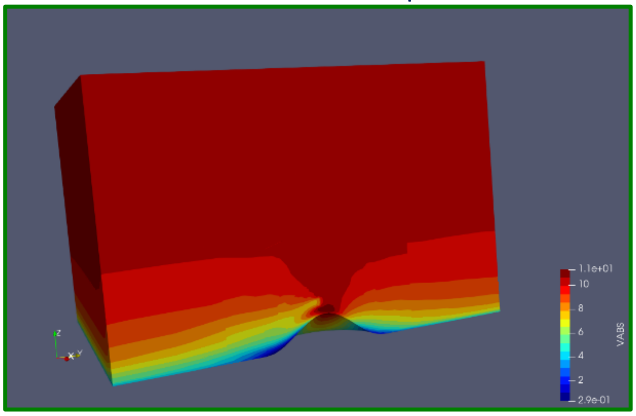


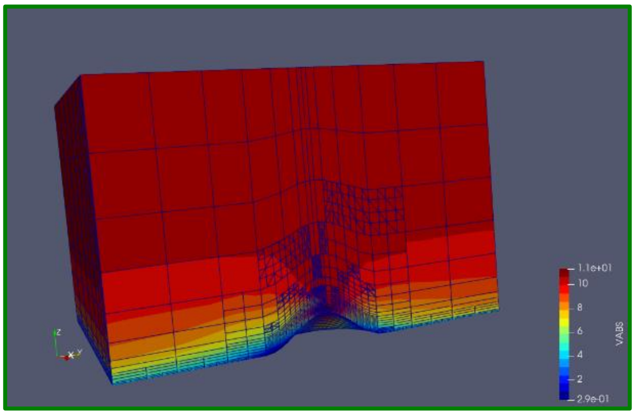
Laminar Pipe flow at Reynolds number=10: It can be seen that the shear-thinning effect of a Pseudoplastic non-Newtonian fluid produces a very flat velocity profile in the core of the flow

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 worked with WindSim (founded as Vector AS) and supplied PHOENICS for windfarm 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. 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.

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

4) IPSA (Inter-Phase-Slip Algorithm)

IPSA entails solving full Navier-Stokes equations for each phase. It has been available in, used by, and built into, PHOENICS since 1981. It was developed by Brian Spalding as per the extract below from a Royal Society Memoir:

"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 two new IPSA capabilities:

1) Particle-cluster 4-zone fluidisation drag model for IPSA

This model 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.

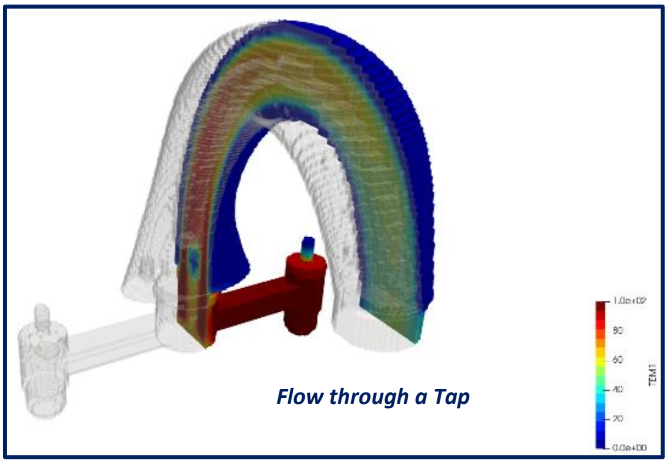
2) IPSA Extension to include Kinetic Theory of Granular Flow (KTGF)

IPSA allows particle-particle interactions by implementing several models for the solids stress tensor, all based on the kinetic theory of granular 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-2022 to handle, more realistically, solid-fluid applications like dense-regime pneumatic lines, riser reactors, and fluidised-bed reactors.

5) Unstructured PHOENICS (USP)



Flow through a Tap

USP means PHOENICS does not always need to use a structured grid, with consequent advantages of computational economy. Cells of unstructured grids to be employed remain predominantly six-sided and, except where obliquely cut by surfaces of physical objects, of cartesian or cylindrical-polar shape. However, their faces may have unequal numbers of cells on opposite sides, usually with one on one side and two or 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 and 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.

6) Sutherland's Law

The law is assumed to be for thermal conductivity. Practical engineering can present problems involving noticeable temperature changes in the flow field which require a model for both thermal conductivity and viscosity.

When viscosity depends on temperature only, PHOENICS already provides Sutherland's law for gases and now provides 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:

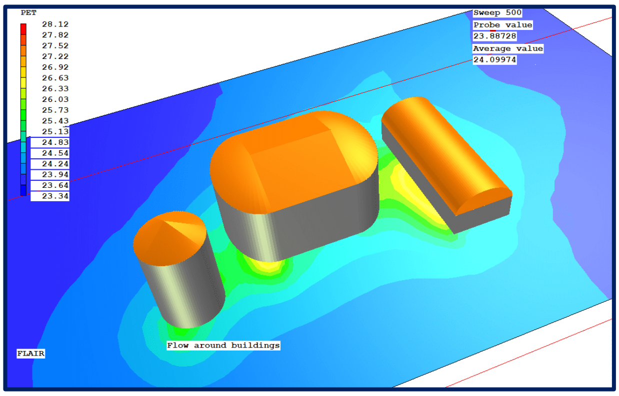
$$\mu = \mu_o \frac{T_o+C}{T+C}\left(\frac{T}{T_o}\right)^{3/2}$$

7) PET comfort index for FLAIR

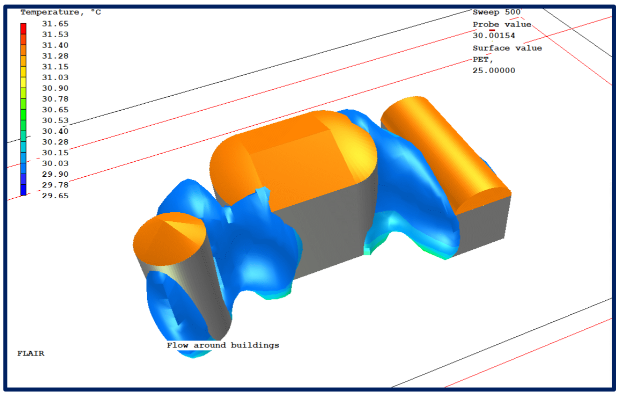
The **P**hysiolgal **E**quivalent **T**emperature (PET) is a thermal comfort index based on a prognostic model of the human energy balance that computes skin and body core temperature, sweat rate and, as an auxiliary variable, clothing temperature.

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

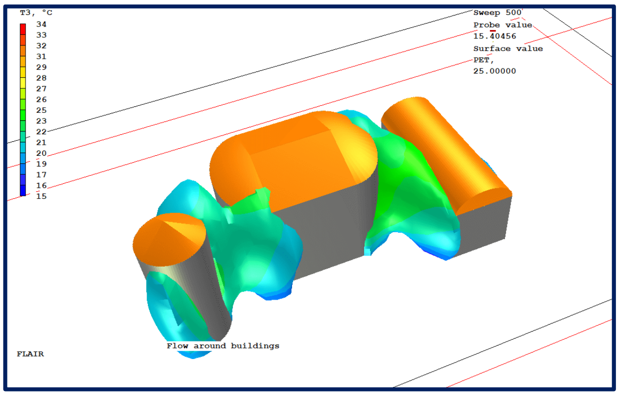
The following images show PET contours.



Flow around a group of buildings



Iso-surfaces of PET 25° coloured by air temperature

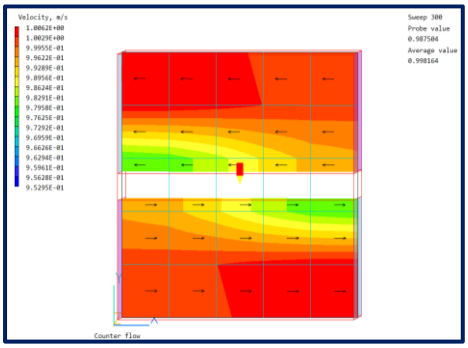


Radiant temperature

8) Double-cut Parsol / Immersol

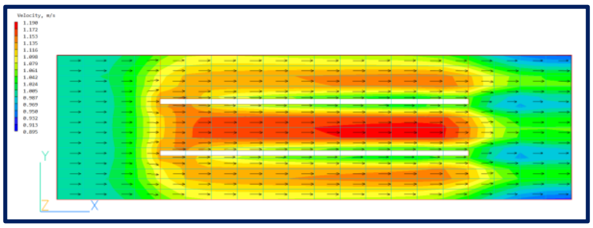
Features have been extended to include:

a) Improved Treatment of sources:

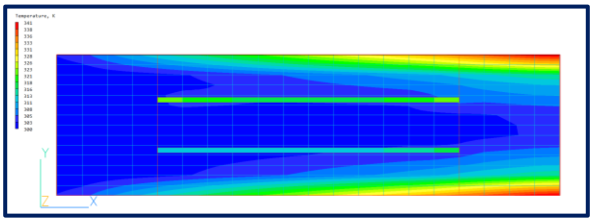


The central row of cells contains INLET and OUTLET sources on either side of the blockage

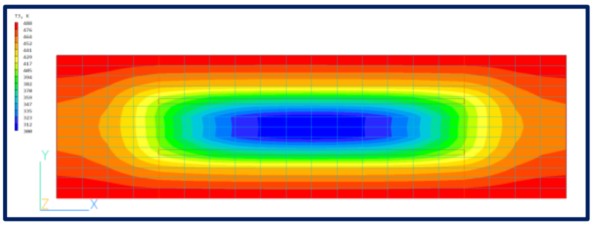
b) Radiation (IMMERSOL) boundary conditions activated for either side of a thin blockage. The following images show radiation between plates in a duct, where blockages are thinner than the cells:



Velocity



Temperature (TEM1)



Radiant Temperature (T3)

c) Improved display in double-cut cells.

9) Print viscous heating source

More accurate determination of a full heat balance from energy sources printed to RESULT is allowed.

10) 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 was volume error for CONWIZ=T, mass error for CONWIZ=F.
- IPSA phase-diffusion flux for Sparsol corrected
- SUN object when #QS2 is 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').
- '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.