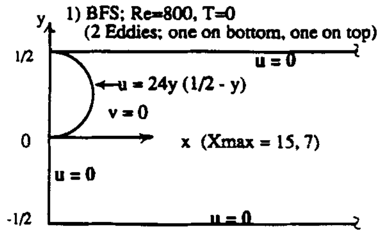
ANNOUNCEMENT

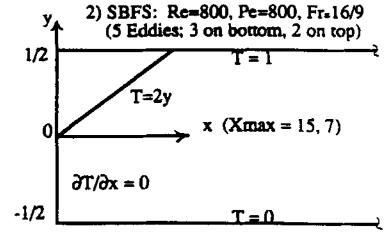
OPEN BOUNDARY CONDITION (OBC) MINISYMPOSIUM

In conjunction with the seventh International Conference on Numerical Methods in Laminar and Turbulent Flow that will be held at Stanford University (Palo Alto, California) in the summer of 1991, we are pleased to announce a one-day pre-conference minisymposium on OBCs for viscous incompressible (laminar) flow. The purpose of the meeting is to compare numerical methods used at open boundaries and to find those that 'work best'. The comparisons/evaluations will be performed via four test problems, defined below, on two computational domains: one that is long enough so that most of the significant physics occurs therein and one that is intentionally too short (and obtained via simple truncation of the long one) so that any OBC is severely tested. The four problems are:

1. Backward Facing Step (BFS); steady isothermal flow.
2. Stratified BFS (SBFS); steady stably-stratified flow.
3. Vortex Shedding Past a Circular Cylinder (VS); unsteady isothermal flow.
4. Poiseuille–Benard Flow in a Channel (PB); unsteady forced plus natural convection.
5. It is possible that a fifth test problem, with a less well-defined flow direction, will be added.

The governing equations, domains, and BC's (except OBC, of course) are given below.





Note: Vel. BC's same as BFS

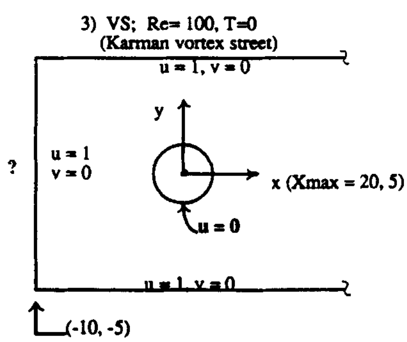
$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u}\cdot\nabla\mathbf{u} = -\nabla P + Re^{-1}\nabla^2\mathbf{u} + Fr^{-1}\mathbf{k}T$$

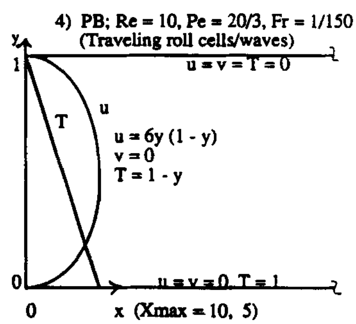
$$\nabla\cdot\mathbf{u} = 0$$

$$\frac{\partial T}{\partial t} + \mathbf{u}\cdot\nabla T = Pe^{-1}\nabla^2 T$$

↑ k

↓ g





1. Backward-facing Step: Proposed Benchmark Solution
by Dave Gartling, Sandia National Lab., Albuquerque

Domain: 1 × 30

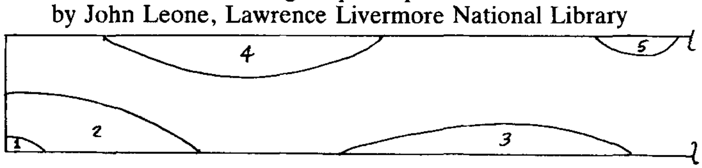
Method: GFEM (SS); 9/3 ($Q_2 - P_1$) element

Grid: 20 × 400 = 8000 elements; 32841 nodes, 74,103 unknowns: (20 × 300 uniform mesh for $0 \le x \le 15$; graded 20 × 100 mesh for $15 \le x \le 30$)

Results:

1. Recovery to plane Poisieulle flow was very nearly achieved—thus OBC is "perfect"
2. Maximum P occurs at $x \equiv 15$ (!); so $\partial P/\partial x \equiv 0$ at exit of "long" mesh.
3. Lower Eddy: Length = 6.09
   Vortex Center: $x = 3.35, y = -0.20$
   ψ at VC: 0.0342
   ζ at VC: 2.285
4. Upper Eddy: Starts at $x = 4.85$
   Ends at $x = 10.48$ Length = 5.63
   Vortex Center: $x = 7.40, y = 0.30$
   ψ at VC: 0.5064
   ζ at VC: −1.321

2. Stratified Backward-facing Step: Proposed Benchmark Solution
by John Leone, Lawrence Livermore National Library



Domain: 1 × 30

Method: GFEM (Transient), 4/1 ($Q_1 - P_0$) element

Grid: 80 × 480 = 38400 elements; 38961 nodes; 155283 unknowns.

Results: 5 Eddies (3 on floor, 2 on ceiling) in $0 \le x \le 10$; 2 strong, 1 medium, 2 weak

Eddy#	Begins at x =	Ends at x =	Length	$\psi^{(1)}_{max/min}$
1	0	0.356	0.356	0.00008/0.00008$^{(2)}$
2	0.356	2.498	2.142/2.153$^{(2)}$	−.0224/−0.0224
3	4.548	8.391	3.843/3.848	−0.0085/−.0085
4	1.210	5.492	4.282/4.297	0.0188/0.0188
5	8.164	10.215	2.051/2.047	+0.0002/+.0002

(1) Relative to separation value

(2) Based on O(h^2) extrapolation from 40 × 240 mesh

3. Vortex Shedding Past A Circular Cylinder: Proposed Benchmark Solution
by Michael Engelman, Fluid Dynamics International

Domain: 10 × 30($-8 \le x \le 22$; $-5 \le y \le 5$; cylinder centered at 0, 0)

Method: (GFEM); 9/3 ($Q_2 - P_1$) element

Grids: 2430 elements; 10,150 nodes; 27,590 unknowns

Results: (Preliminary and incomplete)

	Shedding Period (τ)	Strouhal Number (St)	Wavelength (λ)	Vortex Speed (λ/τ)	Drag Coeff. (C_p)
Coarse mesh	5.74	0.174	5.42	0.945	1.46
Fine mesh	5.73	0.175	5.43	0.949	1.46
Short Mesh*	~5.9	~0.17	—	—	~1.45

* Short mesh ≡ Fine mesh truncated at $x = 4$ (FEM "Do Nothing" OBC's)

— Plot times: U_y at $x = 4$ is passing through 0 from above.

4. Poisieulle-Benard Flow In A Channel: Proposed Benchmark Solution
by Greg Evans and Samuel Paolucci, Sandia National Labs, Livermore

Domain: 1 × 20

Method: Control Volume FDM (MAC grid)

Grid: 40 × 400 = 1600 elements; ≈16600 nodes; ≈ 66000 unknowns

Results:

Wavelength	Period	"Speed"	$\lvert V_{max} \rvert$ at $y = 1/2$	$\overline{Nu}$
(λ)	(τ)	(λ/τ)		
1.512	1.322	1.14	5.03	2.567