# Chemical Engineering 512

## *Nuclear Reactor Transient Modeling*

Lecture 11

Numerical Stability

# Chemical Engineering 593R

## RELAP5-3D

Lecture 11

Numerical Stability

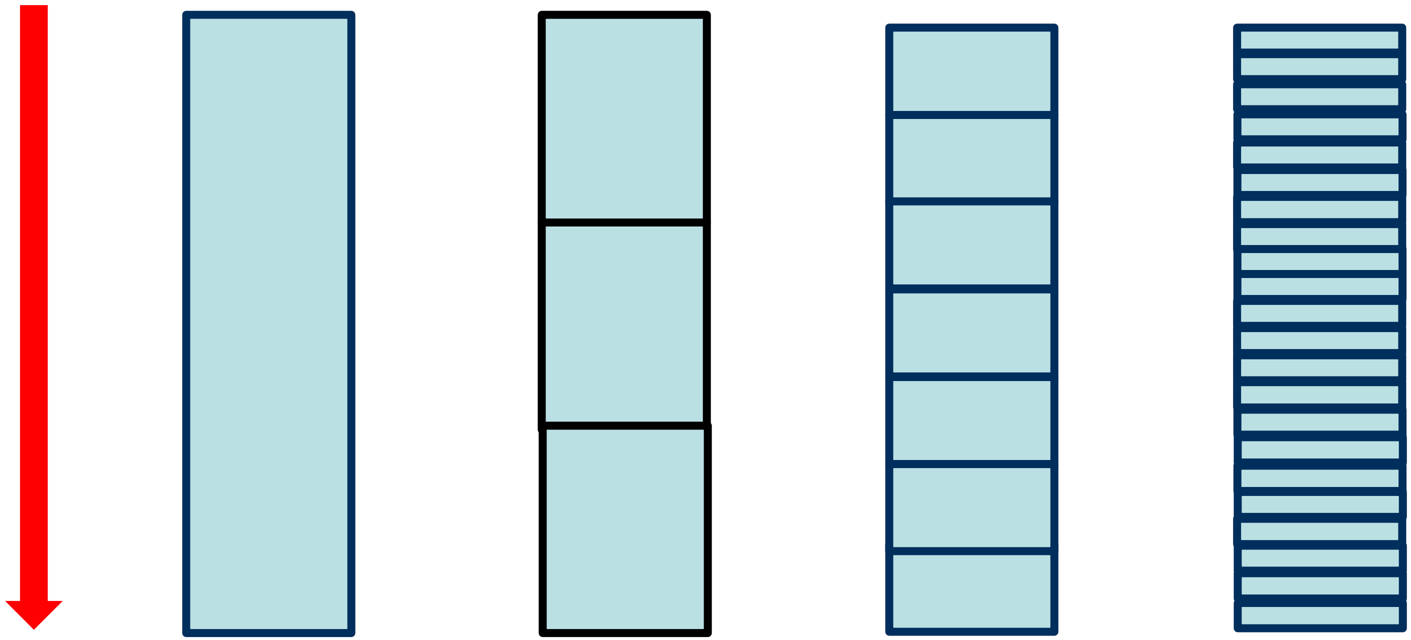
# Spiritual Thought

“I have always been amazed that [Jesus] could sleep through a storm on the Sea of Galilee so serious and severe that His experienced fishermen disciples thought the ship was going down. How tired is that? How many sermons can you give and blessings can you administer without being absolutely exhausted? The caregivers have to have care too. You have to have fuel in the tank before you can give it to others.”

# Objectives

- Nodalization
- Courant limit
- Practice numerical stability

# Nodalization



# Courant Limit

- The minimum time it takes for the fluid to pass through a volume is the Courant limit.
- The problem time step must be below this value or the fluid will “skip” volumes

$$(\Delta t_c)_i = \Delta x_i \frac{\max(\alpha_{fi}^n, \alpha_{gi}^n)}{\max(\left|\alpha_{fi}^n v_{fi}^n\right|, \left|\alpha_{gi}^n v_{gi}^n\right|)} \qquad i = 1, 2, \ldots, N \ .$$

$$\Delta t_c^1 \le \Delta t_c^2 \le \Delta t_c^3 \le \Delta t_c^4 \le \Delta t_c^5 \ .$$

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# Courant Limit Practice

- Pure water is flowing through a single volume at 10m/s. What is the Courant limit when the volume is 4m long and what should the maximum time step be (card 201)

$$(\Delta t_c)_i = \Delta x_i * \frac{\max\left(\alpha_{fi}^n, \alpha_{gi}^n\right)}{\max\left(\left|\alpha_{fi}^n v_{fi}^n\right|, \left|\alpha_{gi}^n v_{gi}^n\right|\right)} \qquad i = 1, 2, \ldots, N$$

# Skipping Cells

- When fluid is flowing fast through a pipe, if pipe volumes are too small, the courant limit will be less than the time step and the fluid will skip the volume.

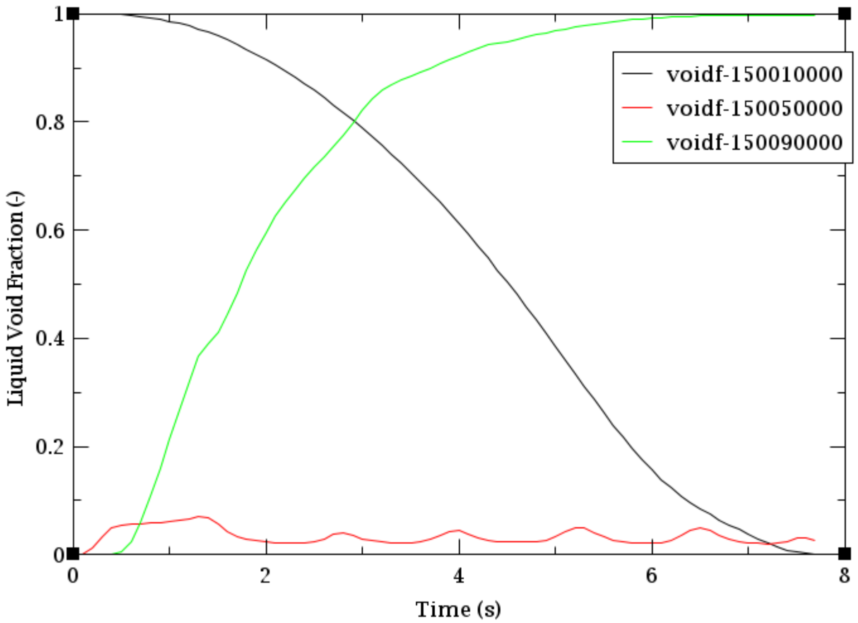
- Why does this matter?

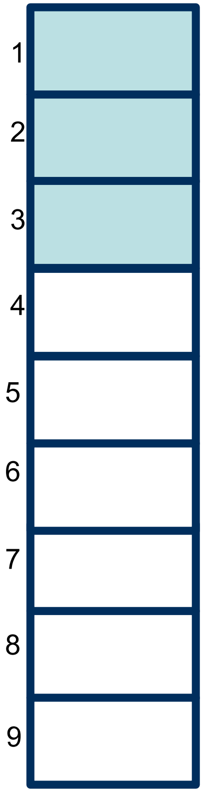
# Computational Time

- Computational time = f(# of hydrodynamic cells)
- Number of heat structures generally increases with hydrodynamic cells
- Minimize number of mesh points in HS
- Subtraction of trips/control variables does little for computational time

# Practice: Nodalization Study

- Remember HW 1?



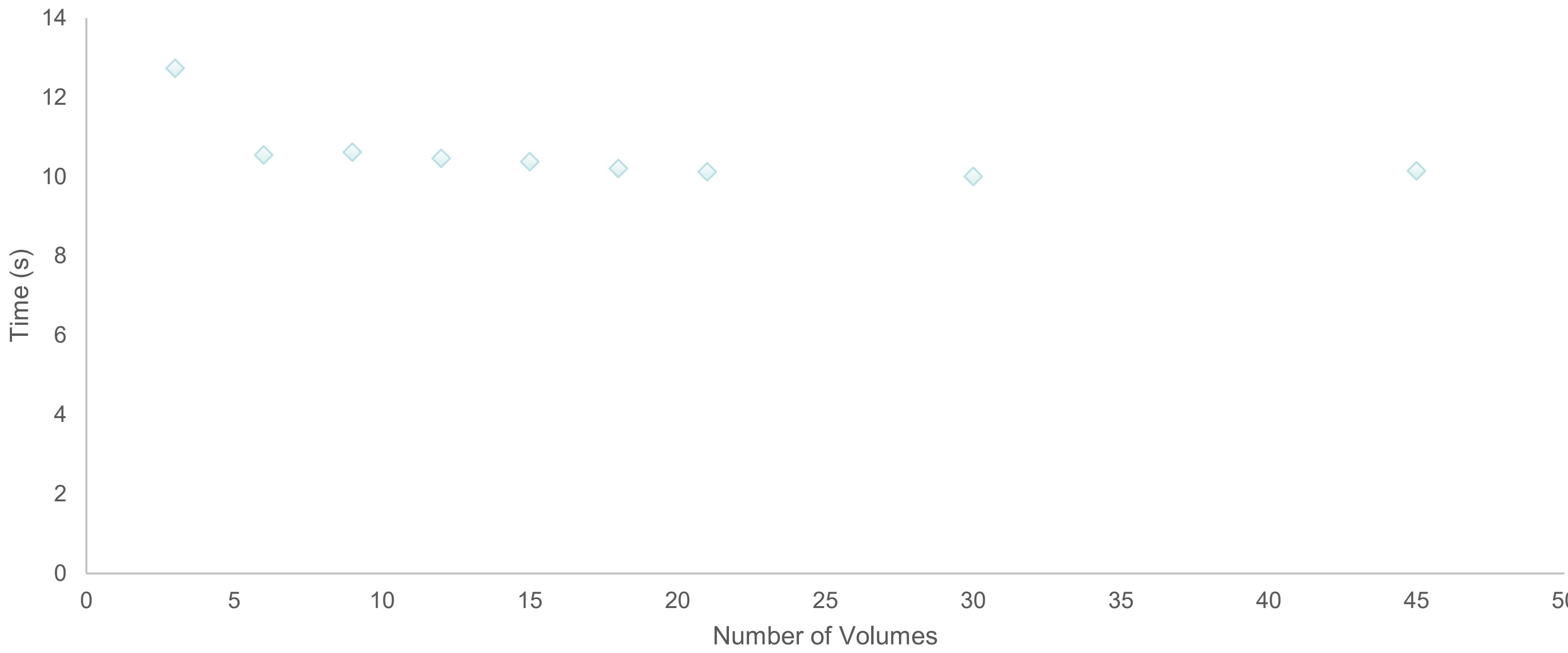
# Practice: Nodalization Study

- What is the optimum number of volumes?
- Time step has already been set to be less than Courant limit
- To compare results we will plot the time it takes for 99.9% of the water to leave the top 1/3 of the pipe

# Practice: Nodalization Study

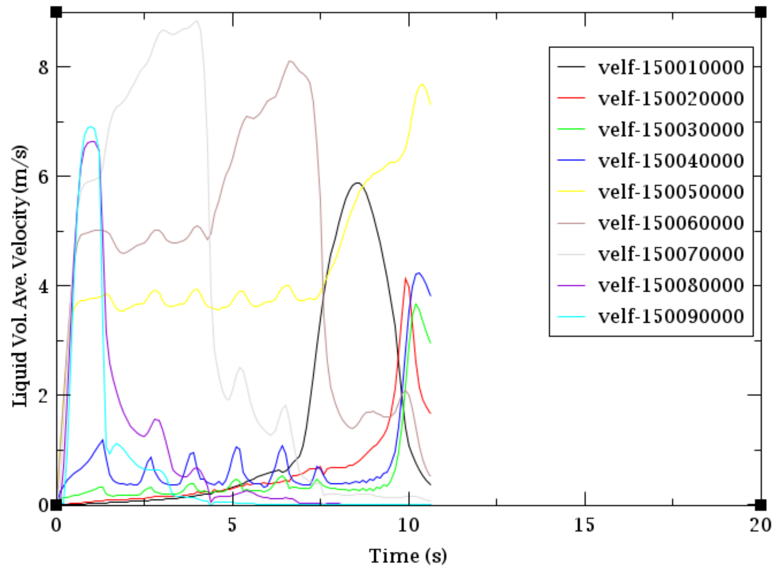
- Conner B. – 3 Volumes
- Kraig - 6 Volumes
- Daniel - 12 Volumes
- Brooklynn - 15 Volumes
- Rusty - 18 Volumes
- Connor L. - 21 Volumes
- Cameron - 30 Volumes
- Jaron - 45 Volumes

# Practice: Nodalization Study



# Practice: Nodalization Study

- How many volumes can we have before changing the max time step of 0.01




$$(\Delta t_c)_i = \Delta x_i \frac{\max(\alpha_{fi}^n, \alpha_{gi}^n)}{\max(|\alpha_{fi}^n v_{fi}^n|, |\alpha_{gi}^n v_{gi}^n|)}$$

$$0.01 = \frac{\Delta x}{9}$$

$$\Delta x = 0.09$$

$$Volumes = \frac{4.5}{0.09} = 50$$

# Why Proper Nodalization?

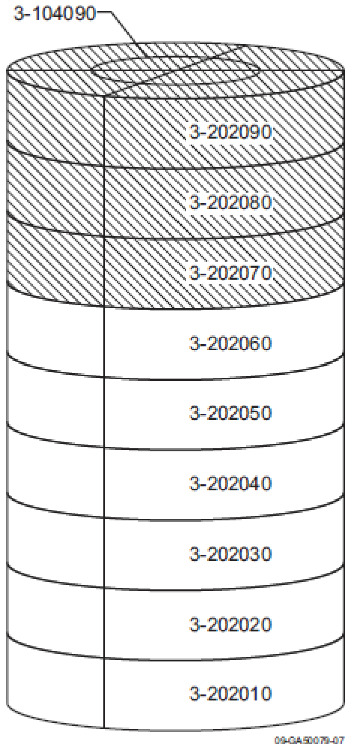
- Can change our results (the example changed by 25%)
- Can lower computation time (this will matter on a larger scale)
- Can lower complexity of deck (no one wants 10,000 volumes to keep track of)
- Ensures you are getting the most accurate answer possible

# Next Class

- Dr. Memmott will cover batch files
- We will learn how to do this same exercise with much less work

# 3D Component

- Basically CFD lite
- Can be helpful if you need to see more detailed 3D behaviors in a tank
- Refer to appendix for input description



# Assignment

- Watch DVD sections 58-63 before next class
- HW 6 due next Tuesday (10/17)