

# Slugging in Pipelines: What You **NEED** to Know

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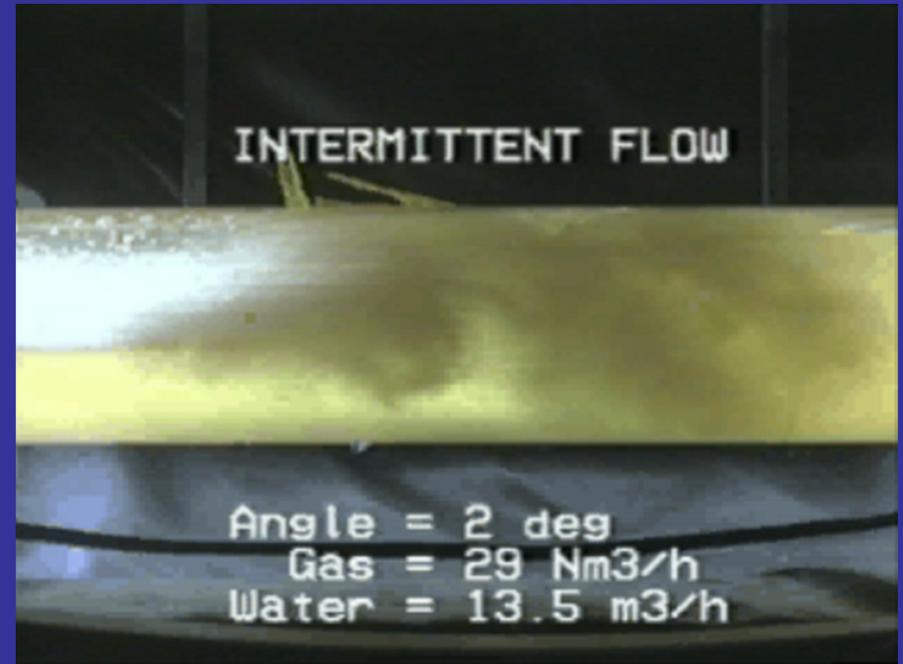
**Schlumberger**

# Outline

- Why Worry?
- Hydrodynamic Slugs
- Terrain Induced Slugs
- Turn Up Slugs
- Pigging Slugs
- Slug Modelling: Where Are We?
- Areas Currently Being Researched
- Conclusions

# Why Worry?

- Damage to facilities
- Separators flooding
- Increased corrosion
- Starving compressors
- High back pressures



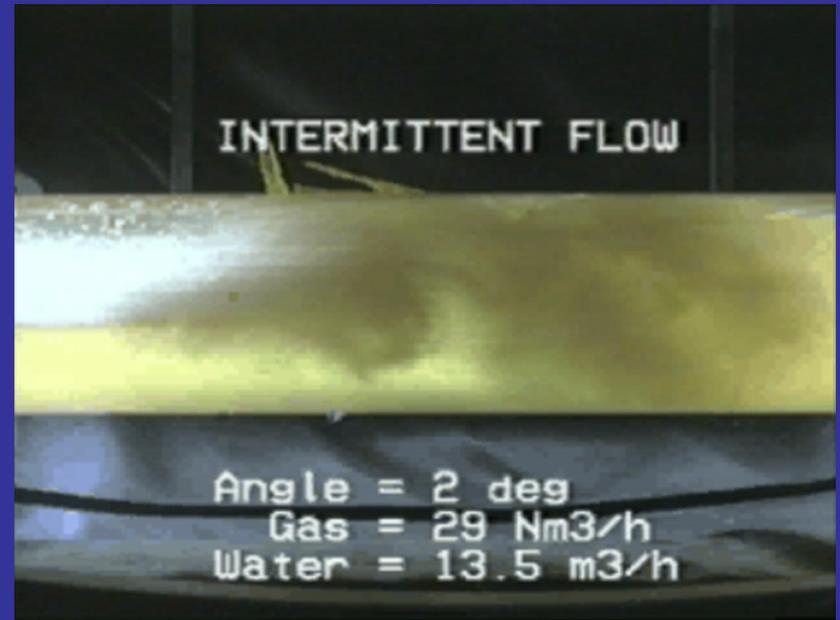
# Hydrodynamic Slugs

Slugs can be created by just flowing

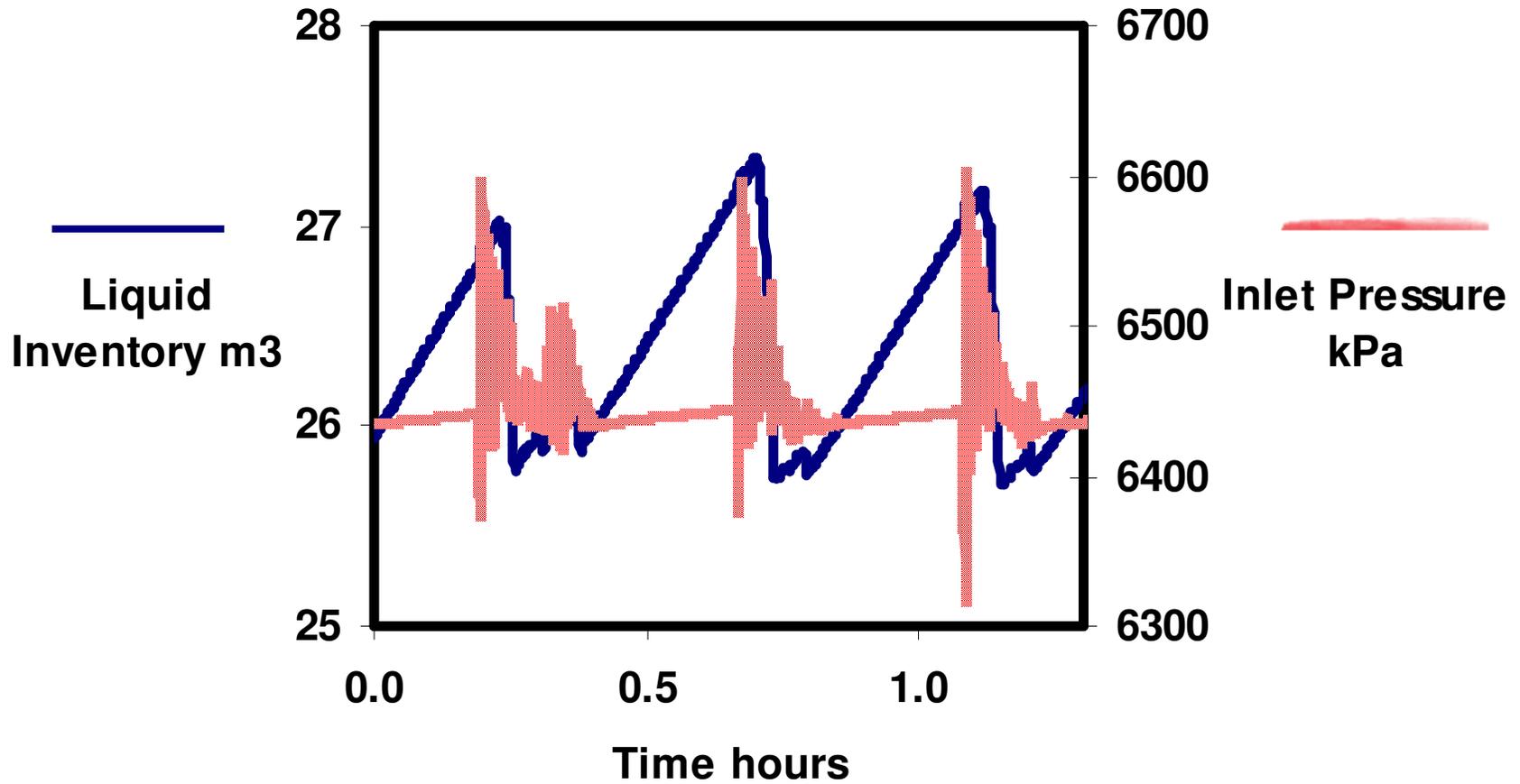


...and there might be lots of them ...

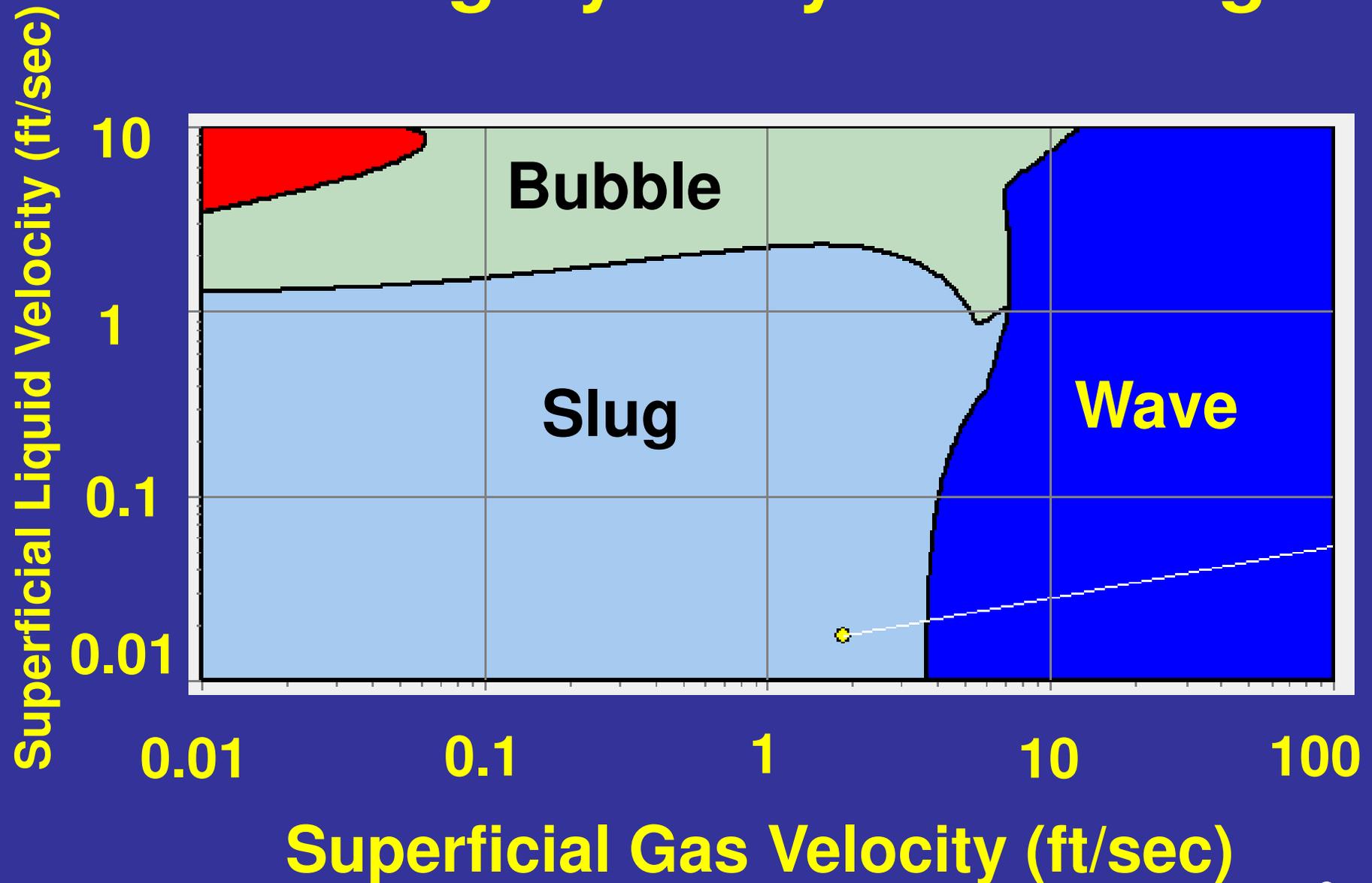
Steady state mechanistic models will account for hydrodynamic slugging (OLGAS, XIAO models)



# Hydrodynamic Slugs

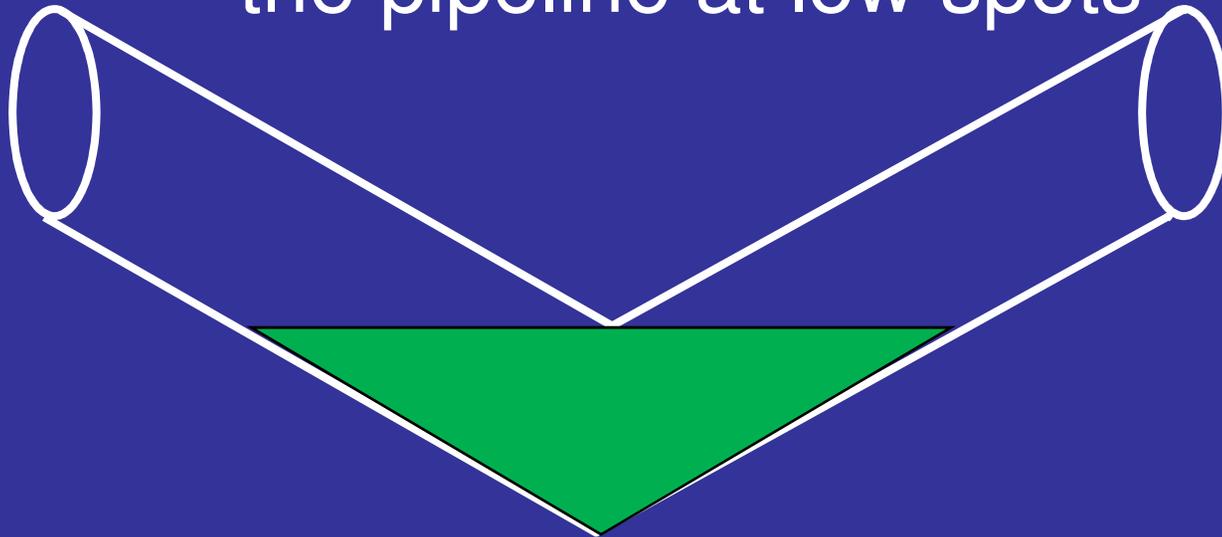


# Avoiding Hydrodynamic Slugs



# Terrain Induced Slugs

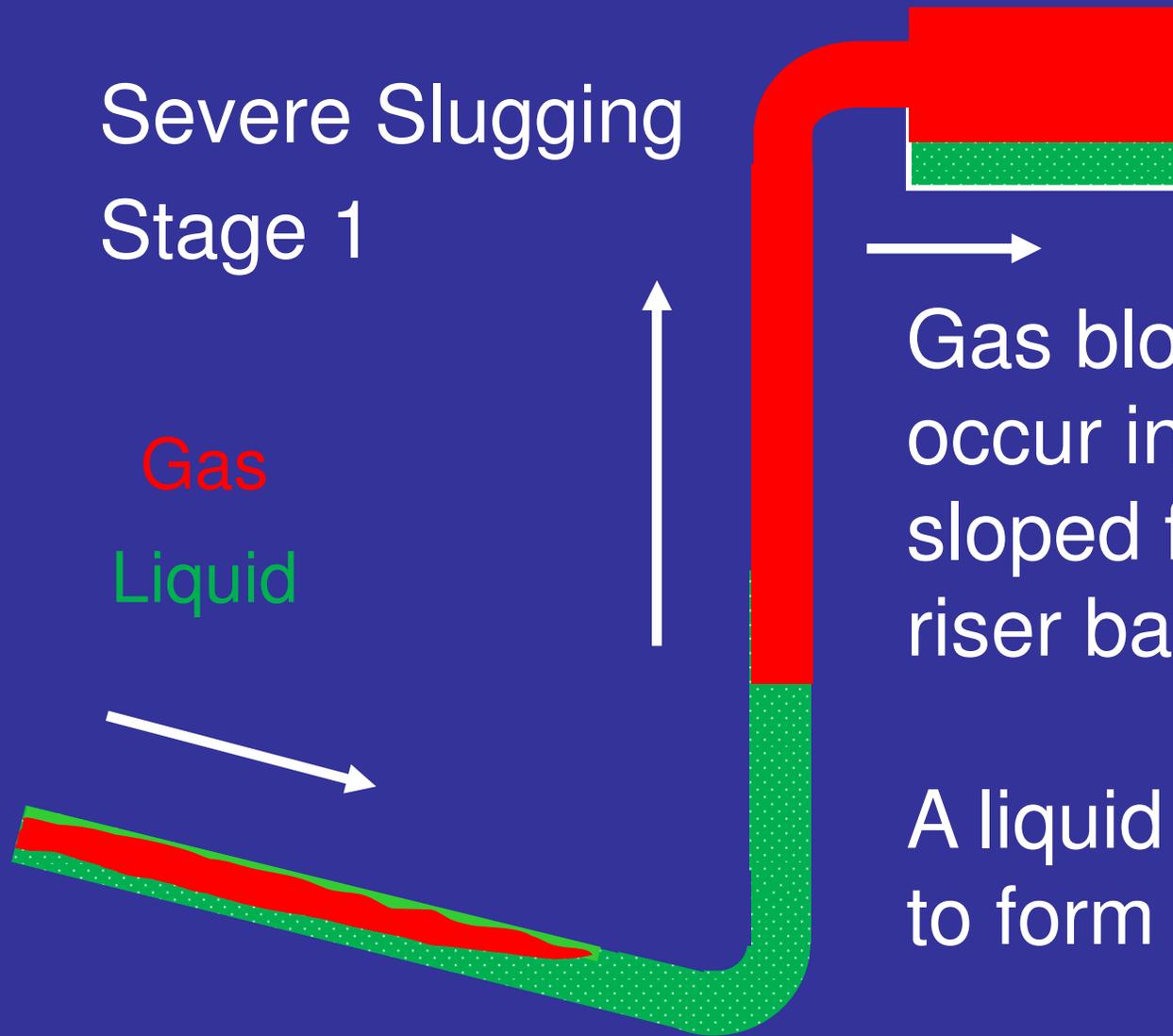
A Slug can be created by liquid trapped in the pipeline at low spots



..... Irregular .....

# Terrain Induced Slug - Severe

Severe Slugging  
Stage 1

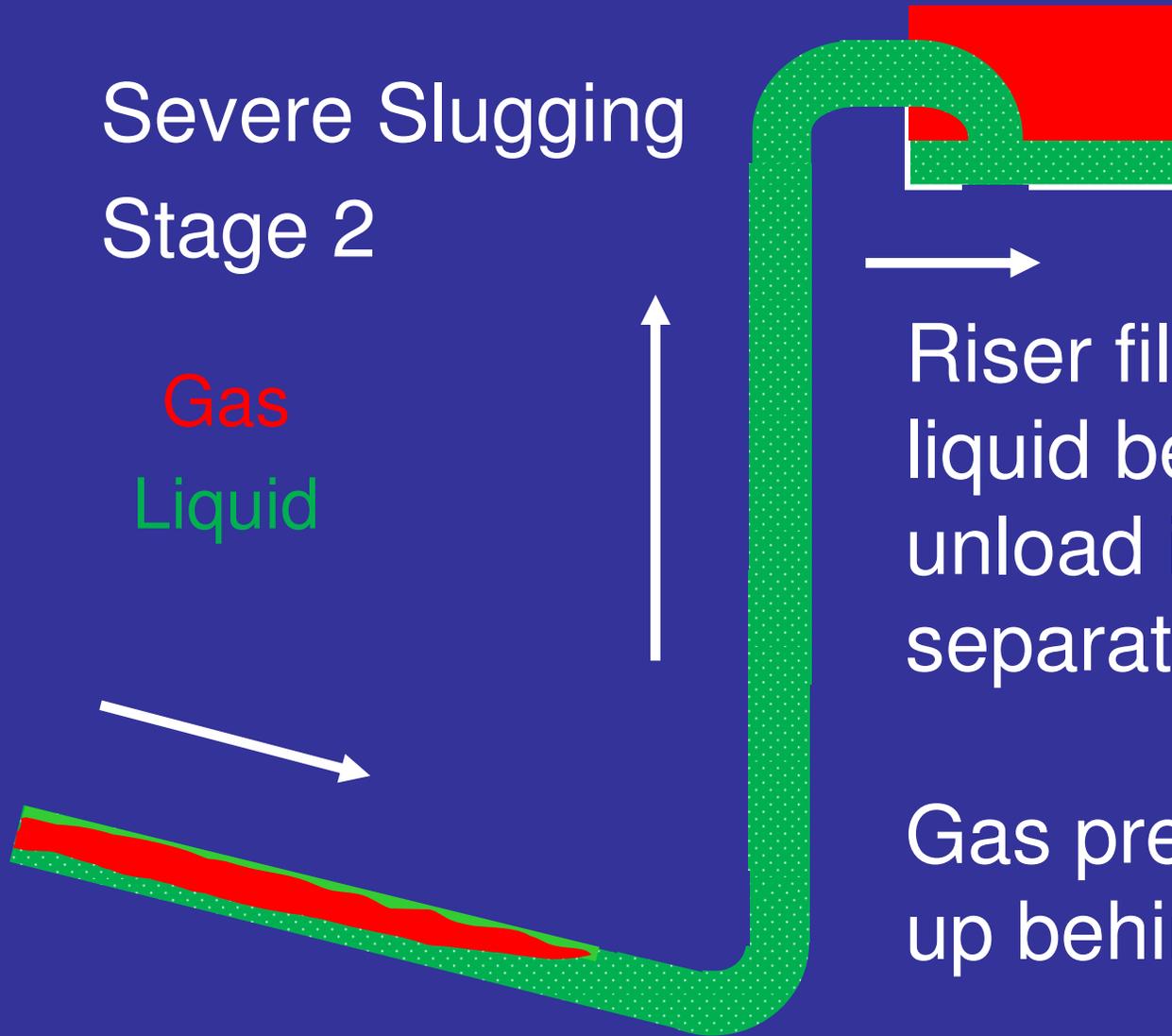


Gas blockage can occur in downward sloped flow line at riser base

A liquid slug begins to form in the riser

# Terrain Induced Slug - Severe

Severe Slugging  
Stage 2



Riser fills, and liquid begins to unload into the separator

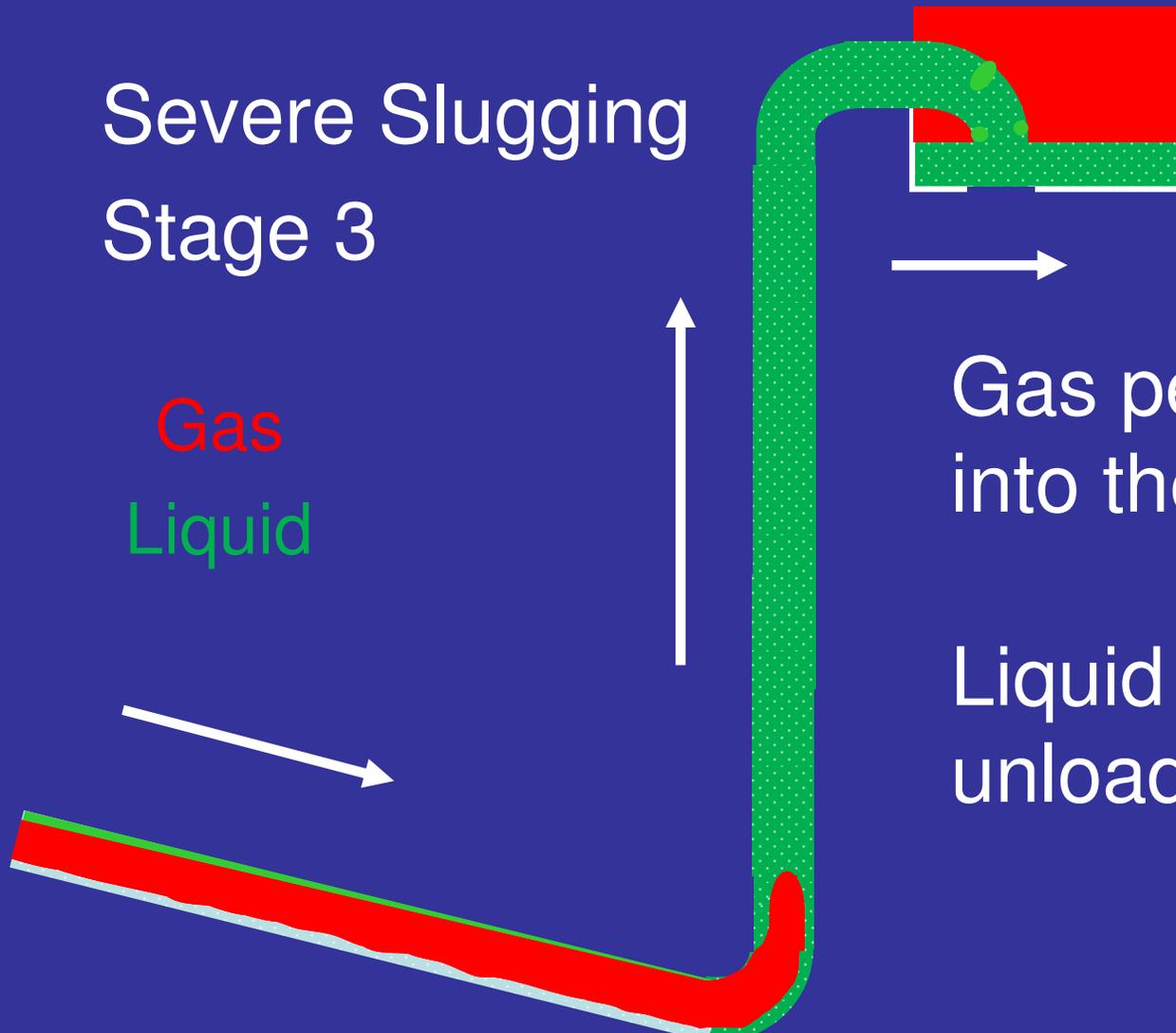
Gas pressure builds up behind slug!!!

# Terrain Induced Slug - Severe

Severe Slugging  
Stage 3

Gas

Liquid

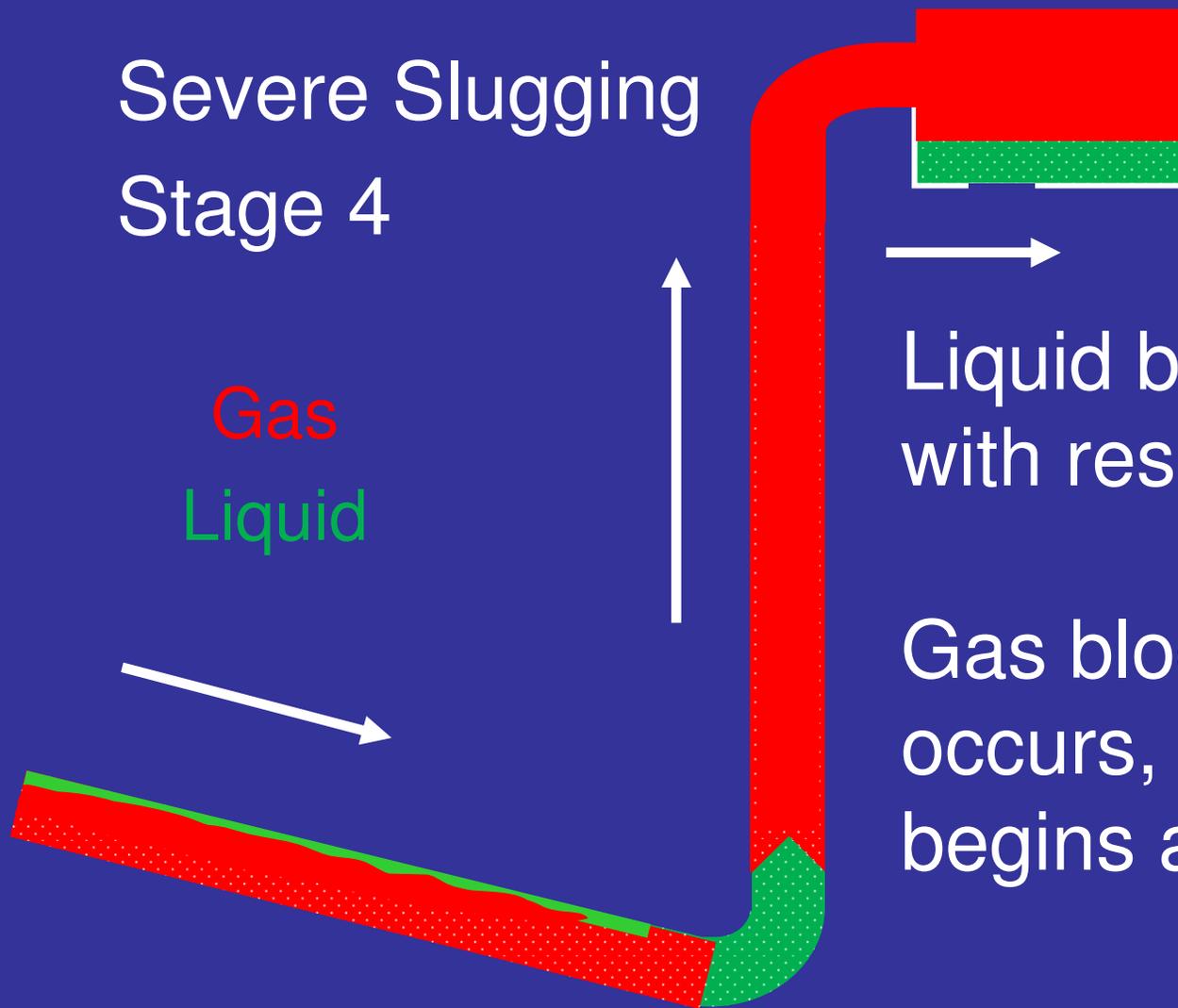


Gas penetrates  
into the riser

Liquid begins to  
unload rapidly

# Terrain Induced Slug - Severe

Severe Slugging  
Stage 4



Liquid blows through  
with residual fallback

Gas blockage  
occurs, and cycle  
begins again

# Terrain Induced Slug

Steady State Multiphase Software:

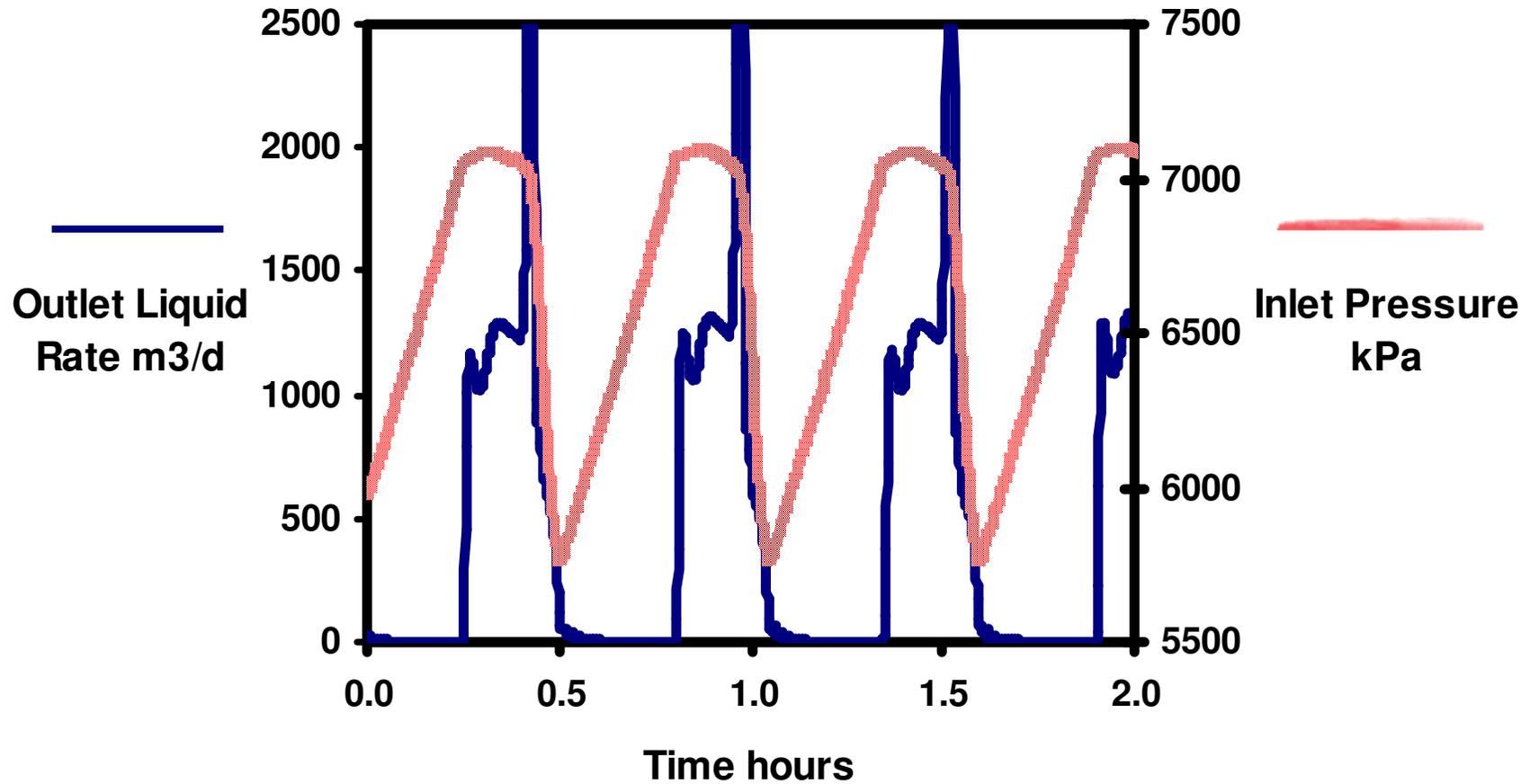
- Severe slugging: Fuchs and Pots correlations give contradictory results but Pots can give indication of potential severe slugging
- Cannot predict other terrain induced slugging
- Check for high liquid holdup in low spots and low liquid velocities

# Terrain Induced Slug

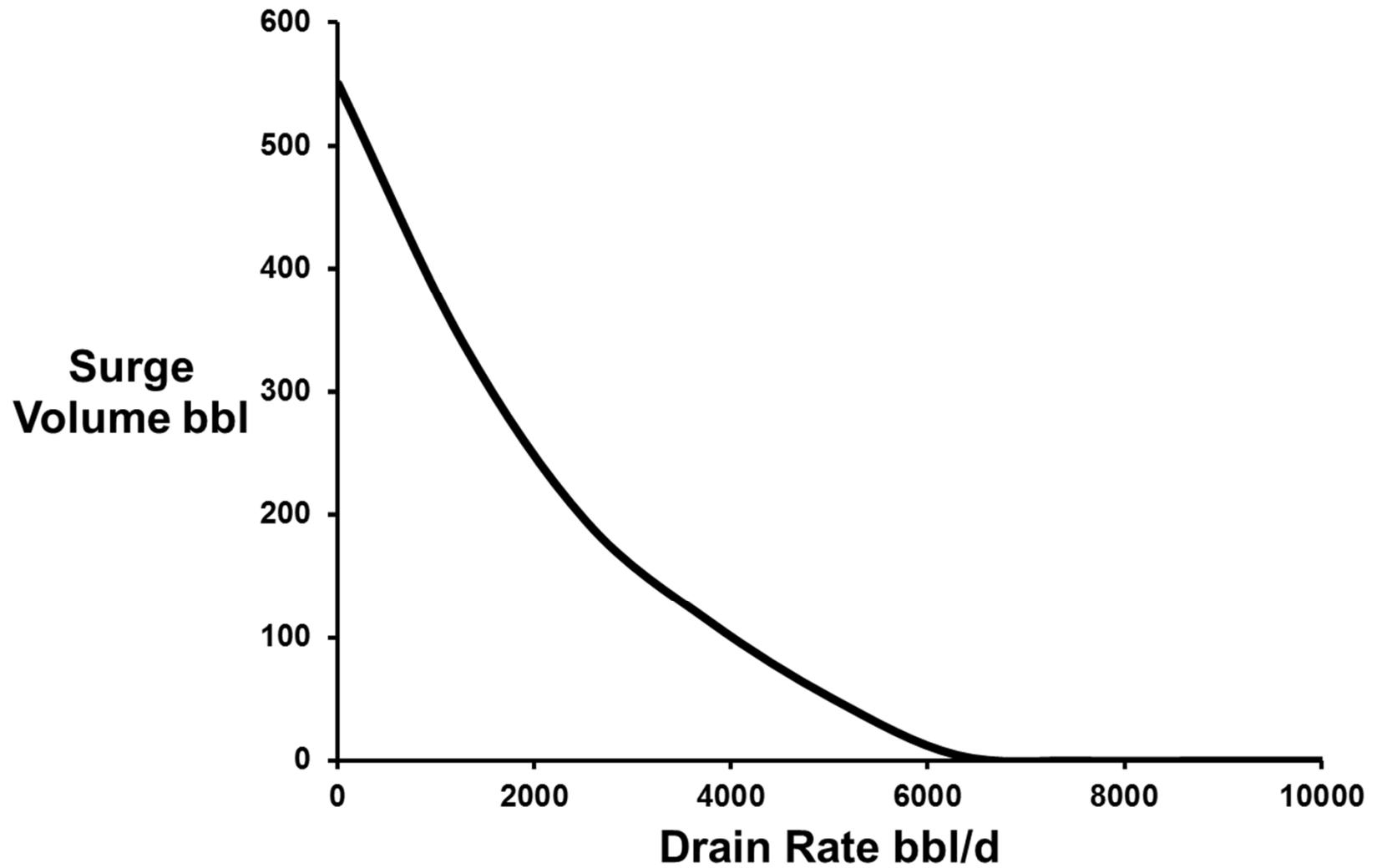
Use a Transient Multiphase Model to Determine:

- Whether terrain induced slugging will occur
- Length and size of slug
- Transit time of slug
- Frequency of slug
- Separator size required to handle the slug

# Severe Slugging Liquid Flow Rate



# Separator Size



# Avoiding Terrain Induced Slugs

In Onshore Pipelines:

- Increase gas flow rates
- Decrease diameter

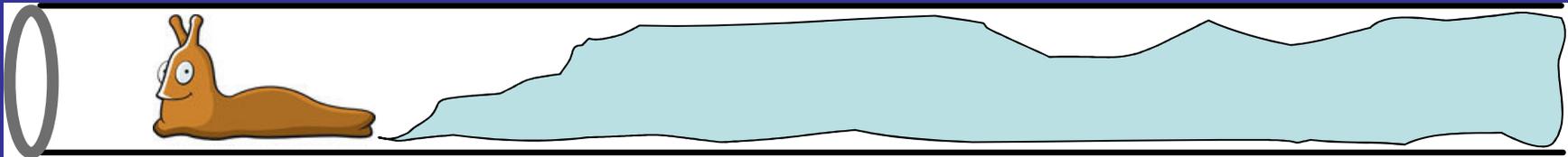
In Offshore Risers:

- Add riser base gas injection
- Increase backpressure

# Turn Up Slugs

A Slug can be created by a Flow Rate change

.....

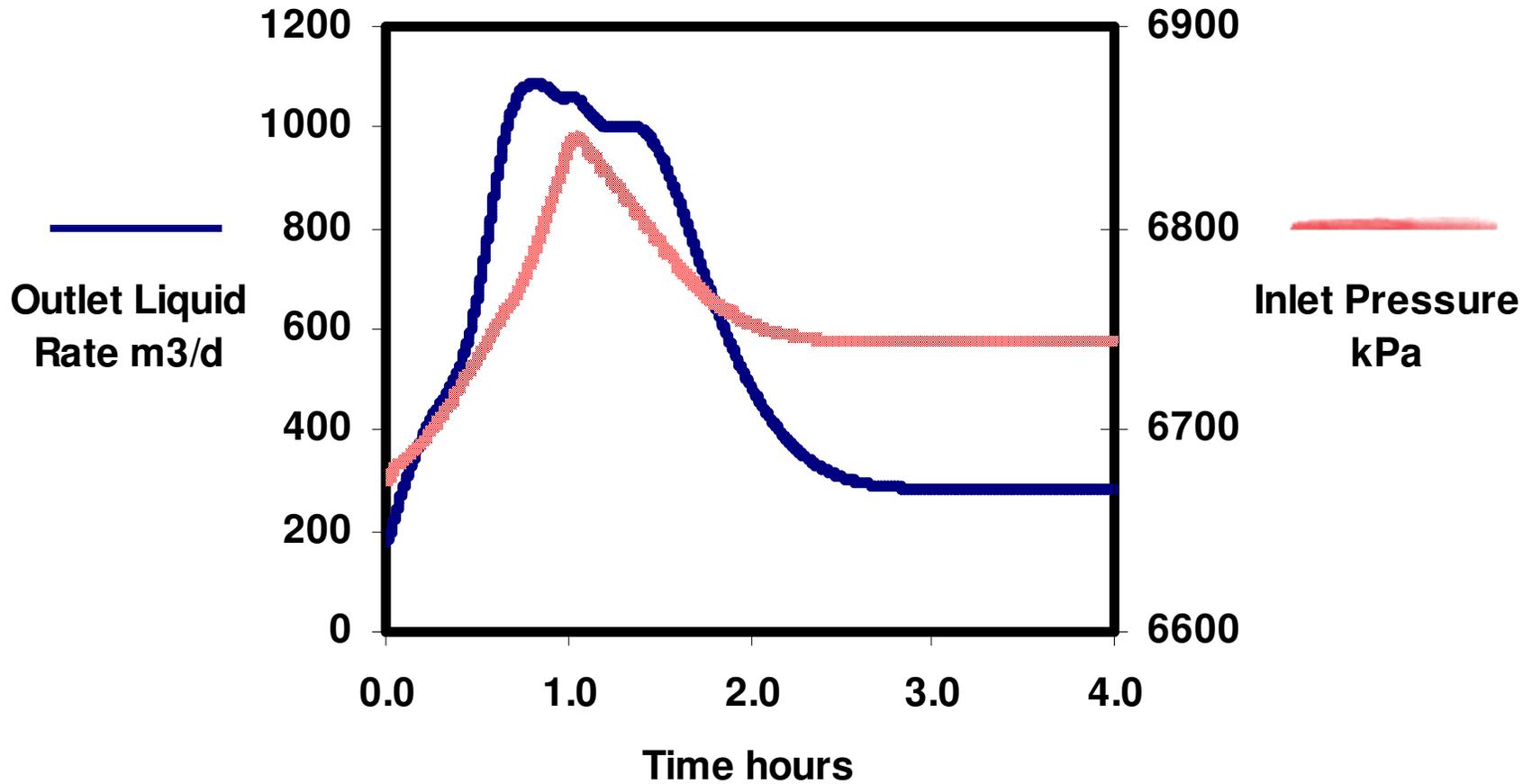


..... but only when it increases .....

Slug volume = difference between liquid holdup at 2 flow rates

Use transient model to rigorously model

# Turn Up Slugs



# Pigging Slugs

Slugs can be created by Pigging

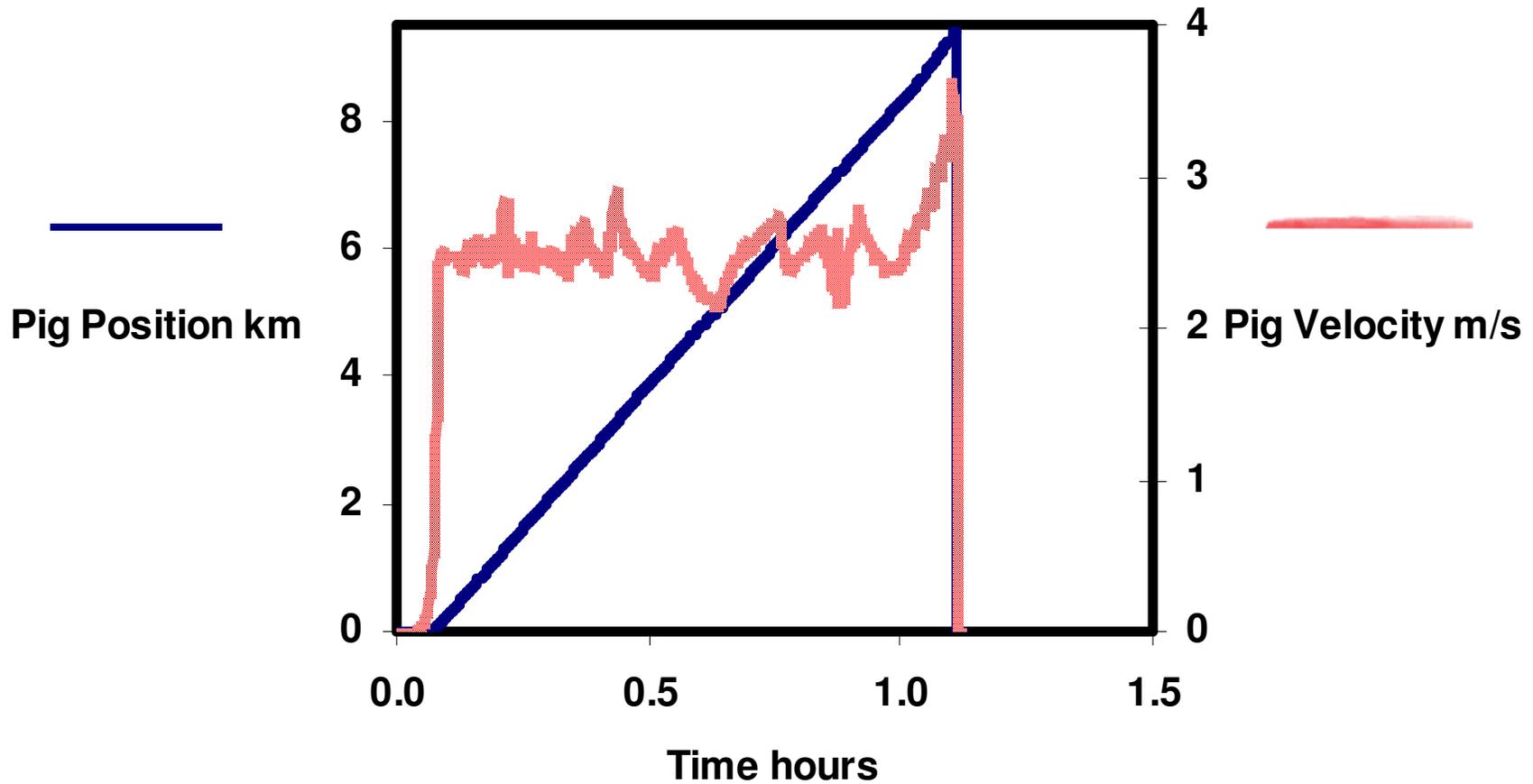


.. but typically just one.....

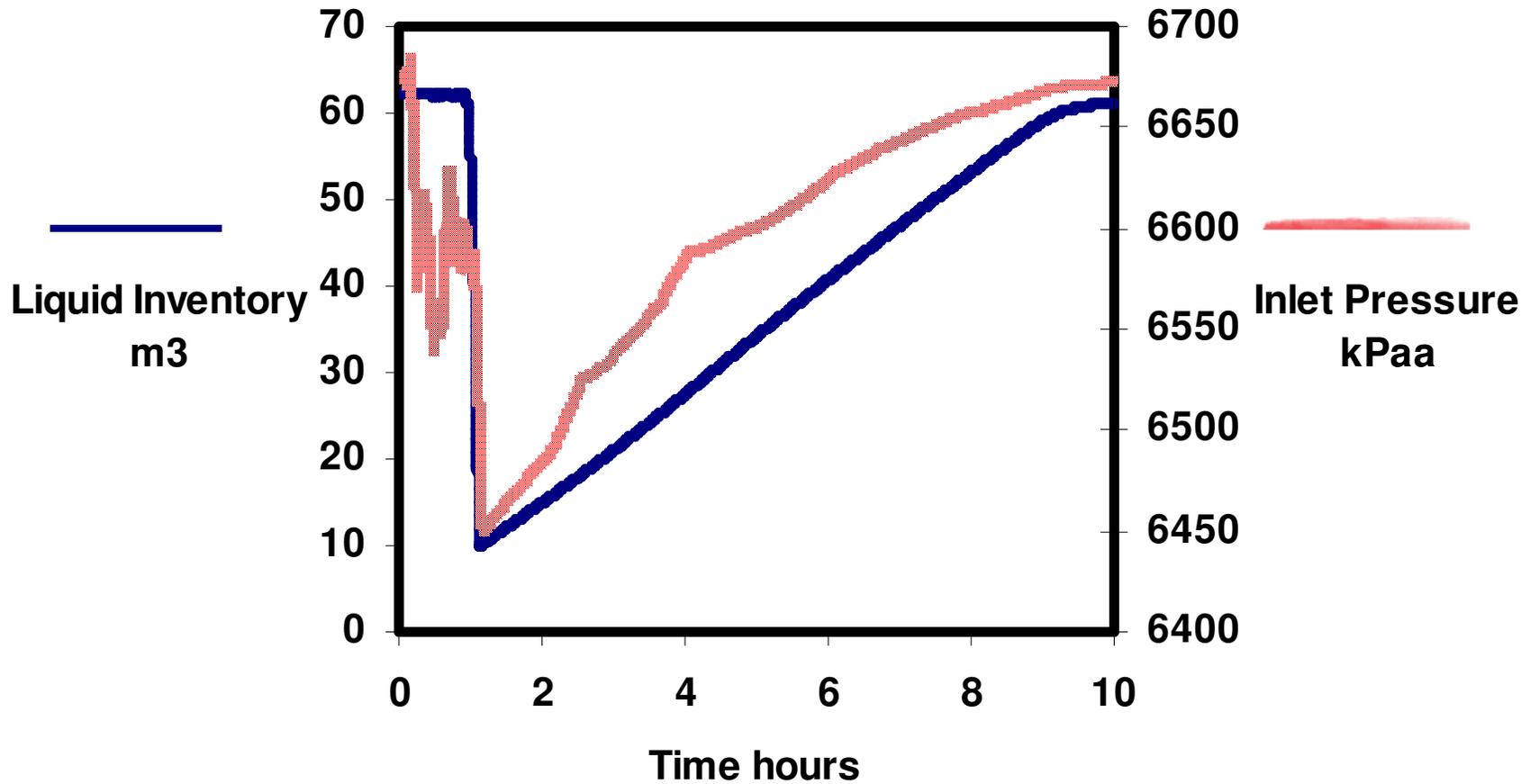
Slug volume = total liquid in pipe minus volume dumped into the separator during pig transit

Use transient multiphase model to accurately model pigging slug size and transit time

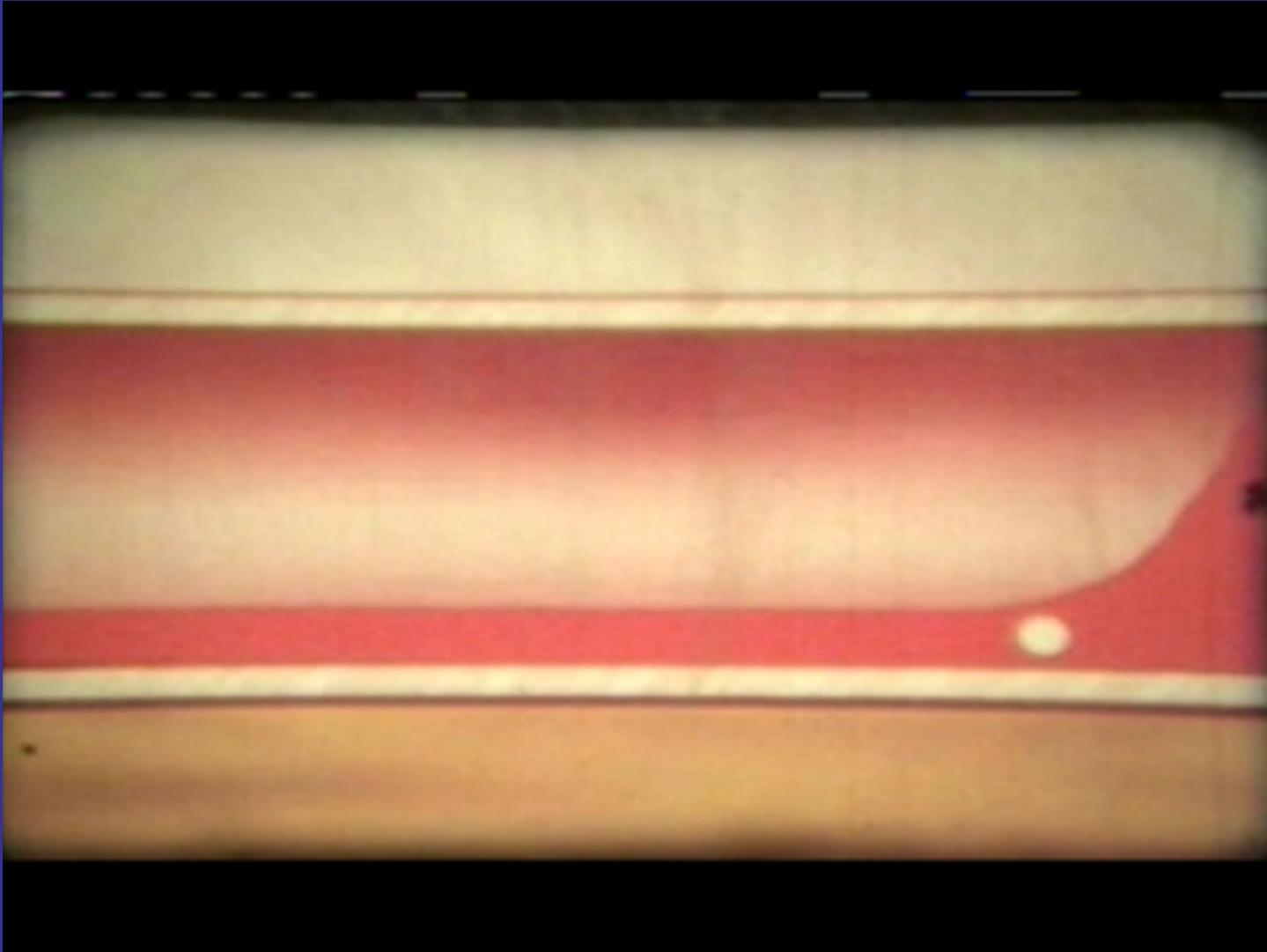
# Pig Position and Pig Velocity



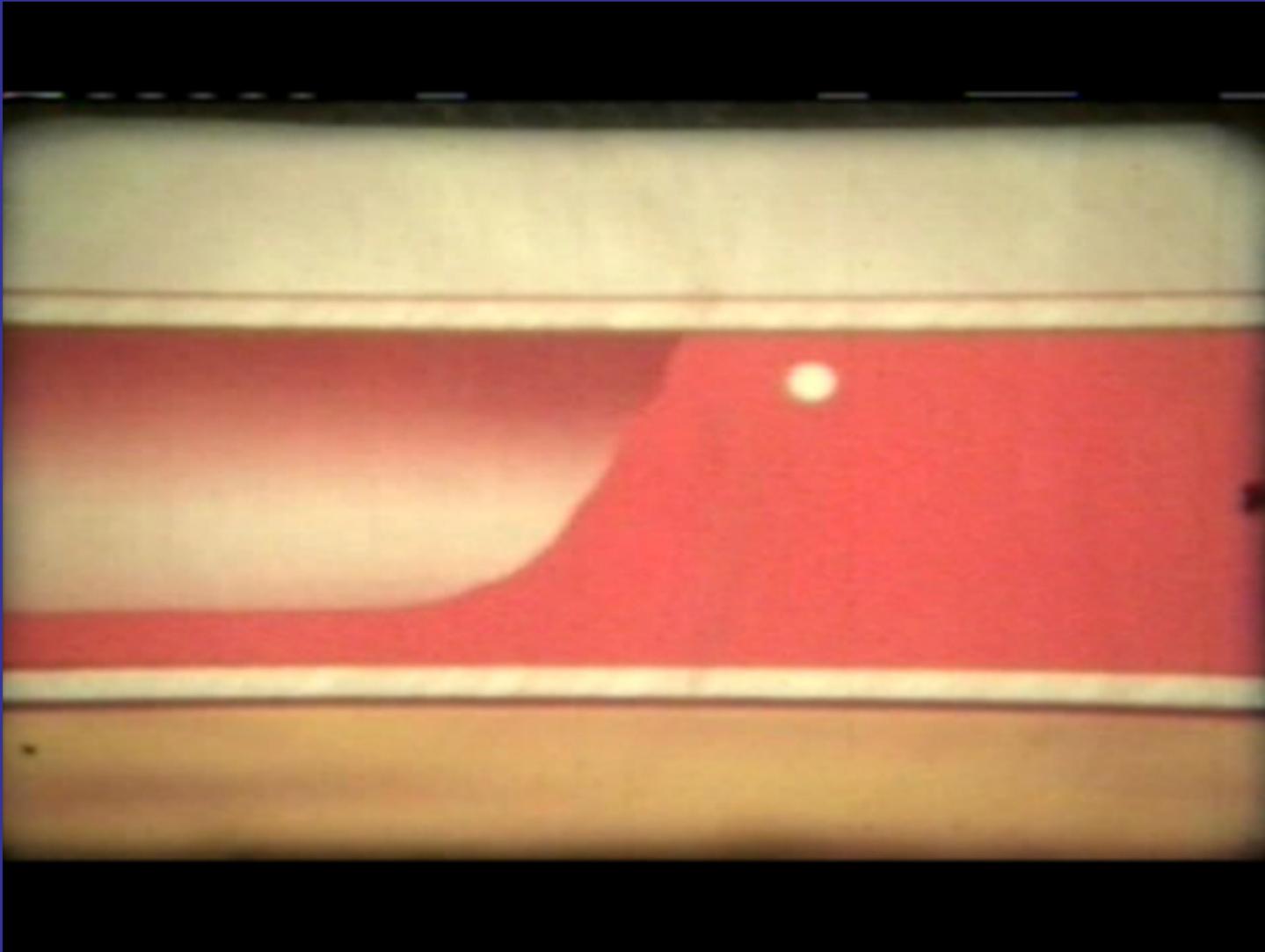
# Liquid Inventory from Pigging



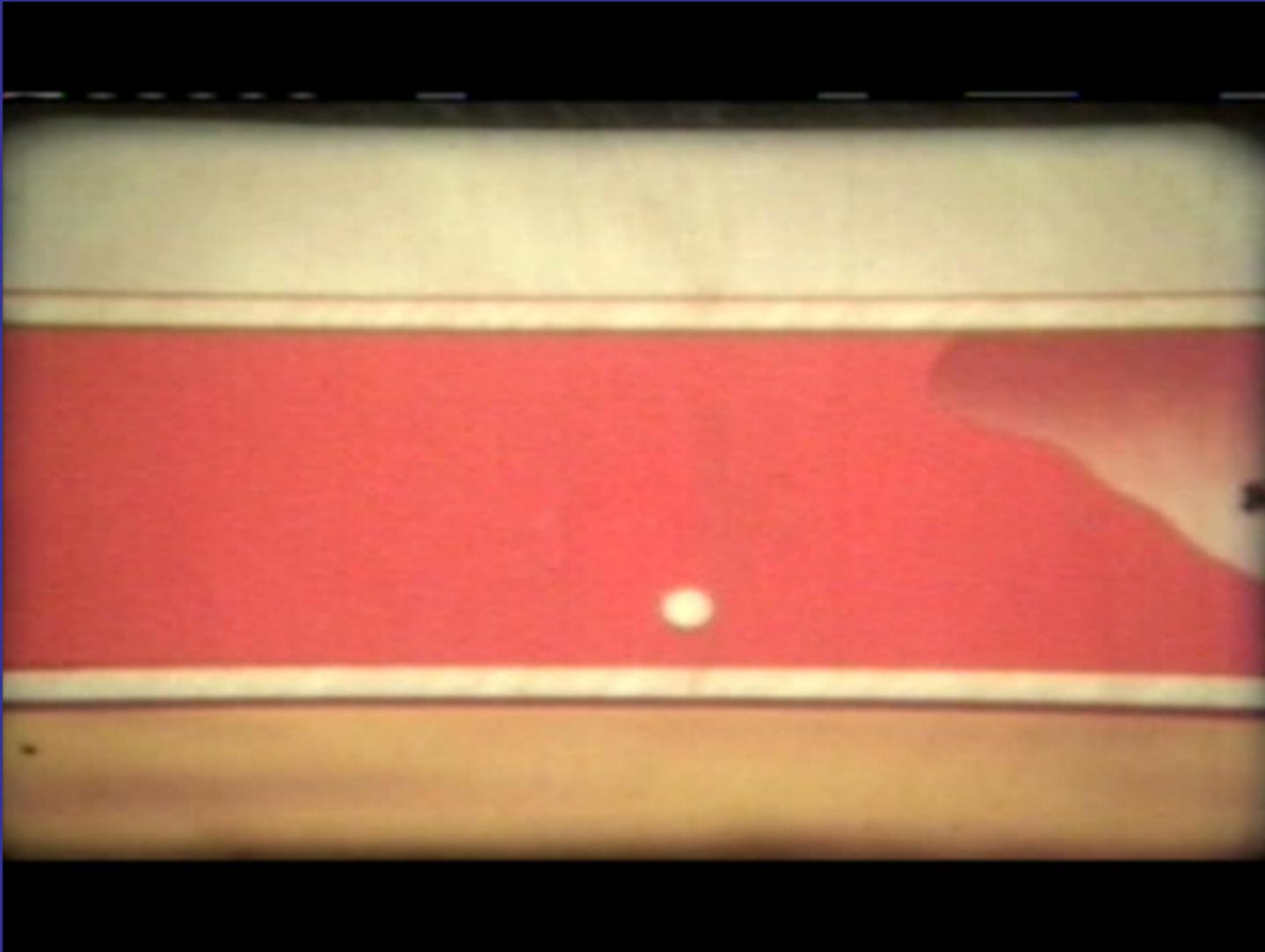
# Slug Modelling: Where are We?



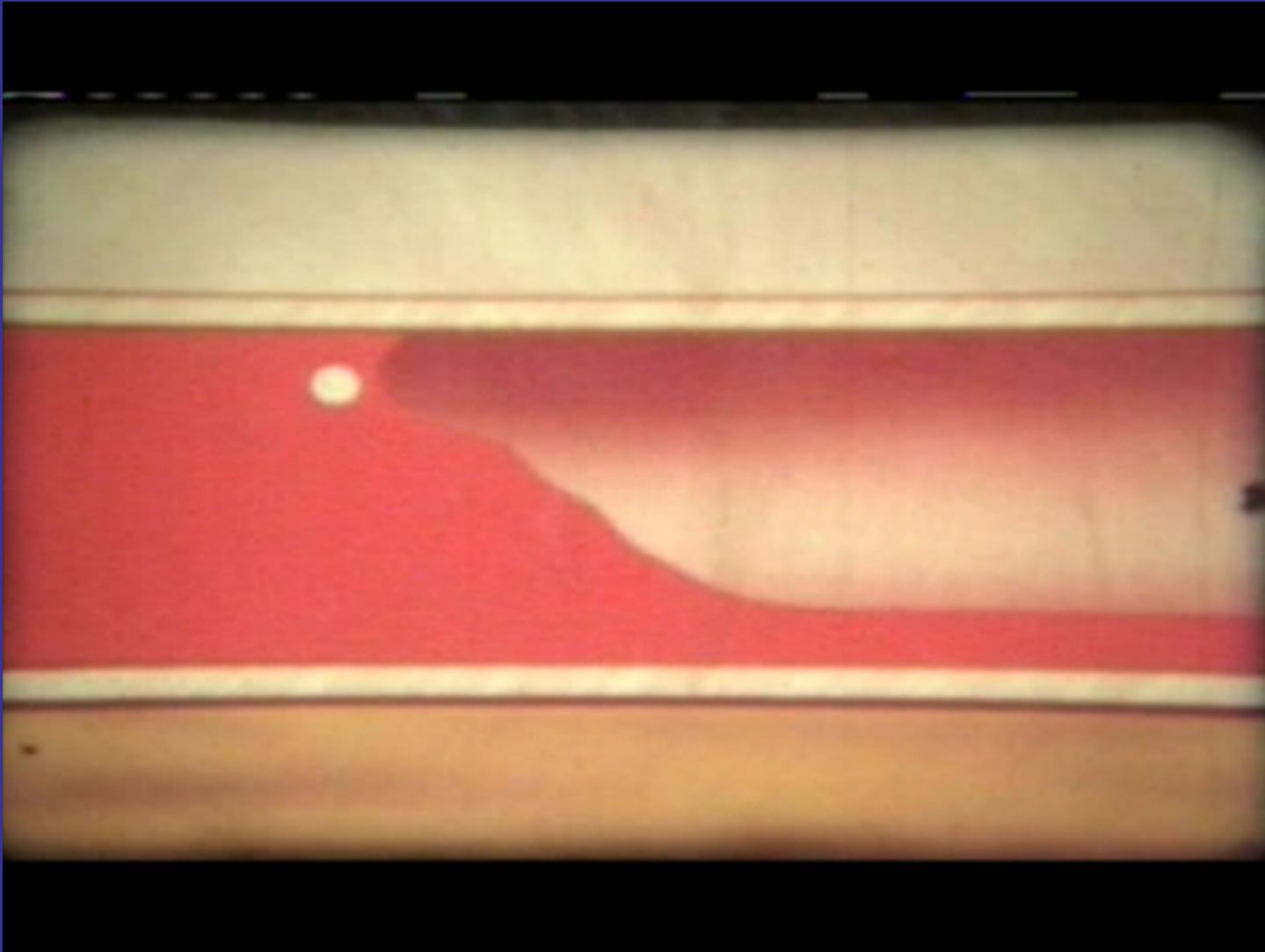
# Slug Modelling: Where are We?



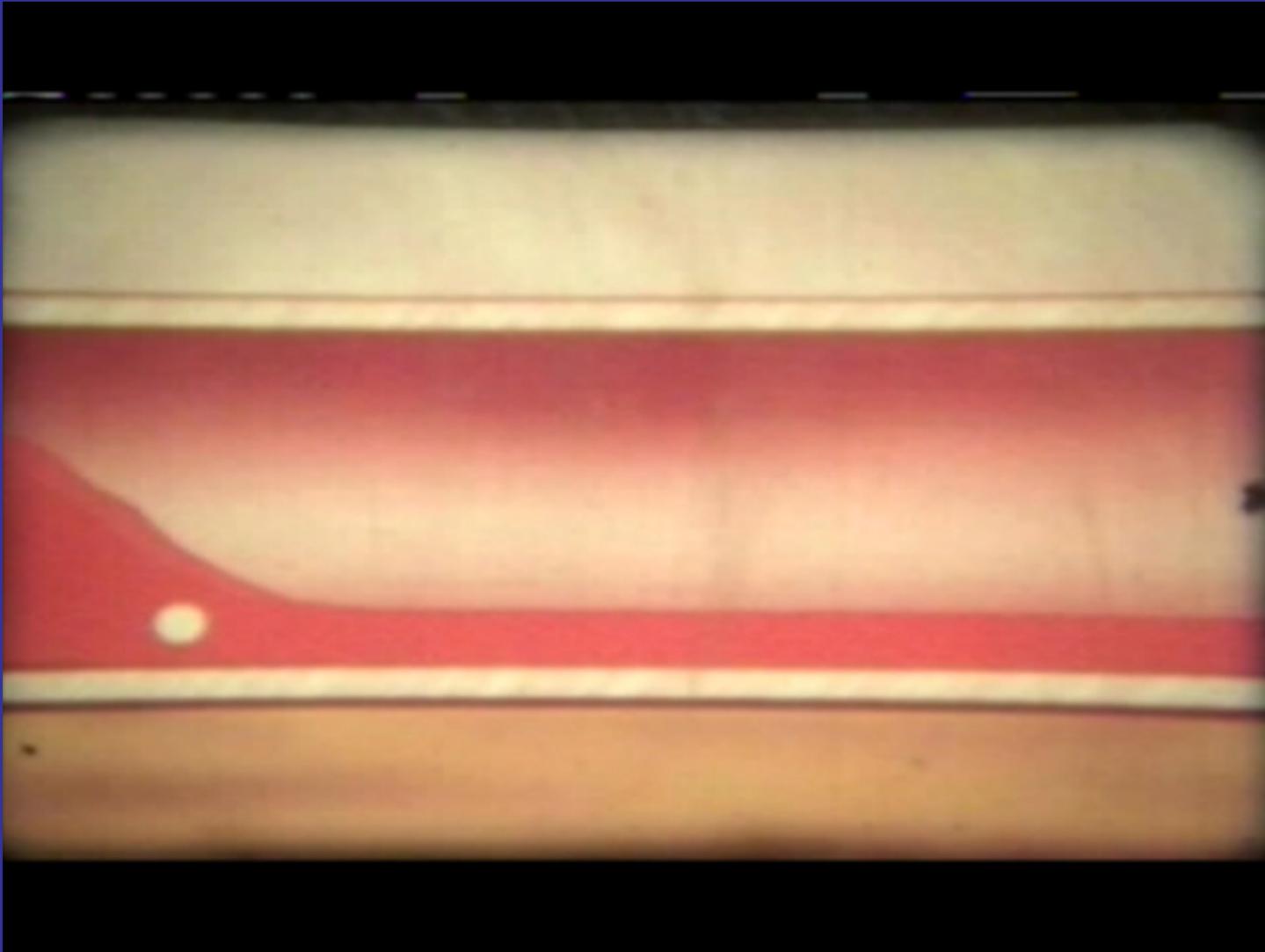
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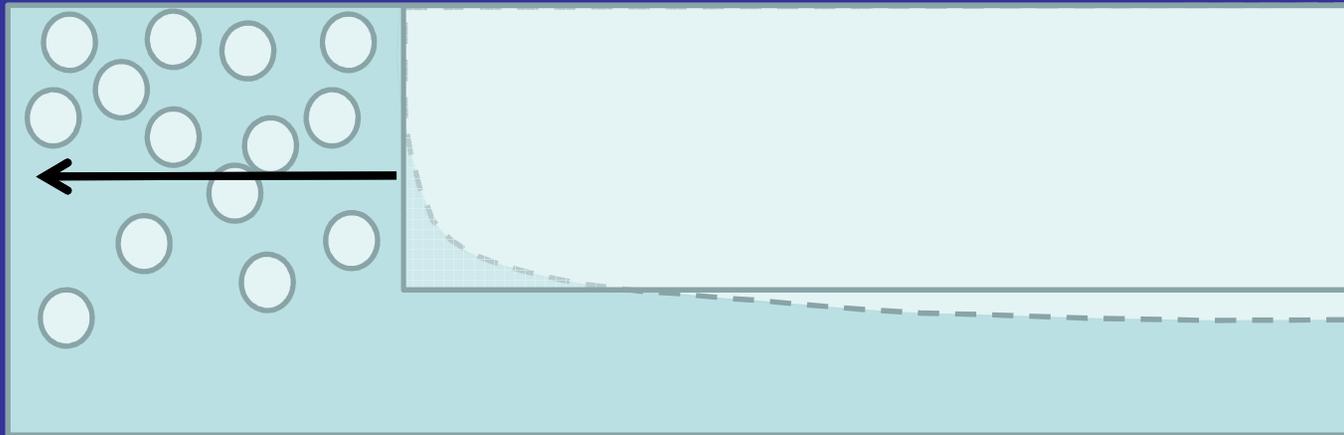


# Slug Modelling: Where are We?



# Slug Modelling: Where are We?

Mechanistic Models Use the “Unit Cell Model”



- Developed by Taitel in 1980's
- Liquid picked up from liquid film = liquid shed
- In mechanistic models now (OLGAS, XIAO)
- Accurate pressure gradients and holdup  
in fully developed slugs

# Areas Currently Being Researched

- Flow pattern transition to / from slug flow in steady state
- More robust models for
  - Liquid holdup in liquid slug (gas entrainment)
  - Gas velocity in liquid slug (turbulence within the liquid slug)
  - Liquid holdup in elongated bubble
  - Liquid slug translational velocity

# Conclusions

- Define what you mean by “slugging”
  - hydrodynamic
  - terrain induced
  - turn up
  - pigging
- Transient modelling provides additional information
- Mechanistic modelling of slug flow understood but still actively being researched and improved

# Acknowledgements

- Dr. Garry Gregory and Dr. Khalid Aziz
  - For creating the multiphase video at the University of Calgary
  - For the images for severe slugging and slug flow
- Pablo Adames
  - For updates on the current state of slug research and parsing the multiphase video
- Schlumberger for sponsoring
  - My time to prepare and present this talk

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