# MEK 4430 Multiphase Flow

Lecture 1 22.08.2014

# Introduction to multiphase flow

- Multiphase flow models were originally developed for the nuclear industry for fluid flows in pipes of steam and condensed steam (water)
- A phase was originally used in the context of a single component water in different phases gas (steam) and liquid (water) hence multiphase flow
- From a modelling perspective, different components such as argon and oil can be treated in precisely the same way as steam and water.
- Multiphase flow is the simultaneous flow of different phases/components where each fluid contributes mass, momentum and energy to the overall flow.

# Introduction to multiphase flow

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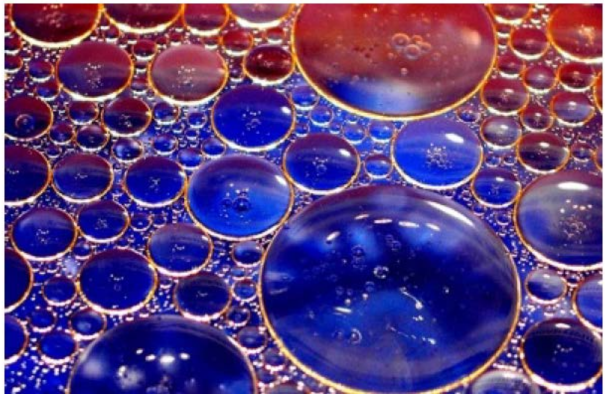
- The *physical properties* of the phases are given by
  - Density $[kg/m^3]$
  - Dynamic viscosity $[kg/ms]$
  - Surface tension $[N/m]$



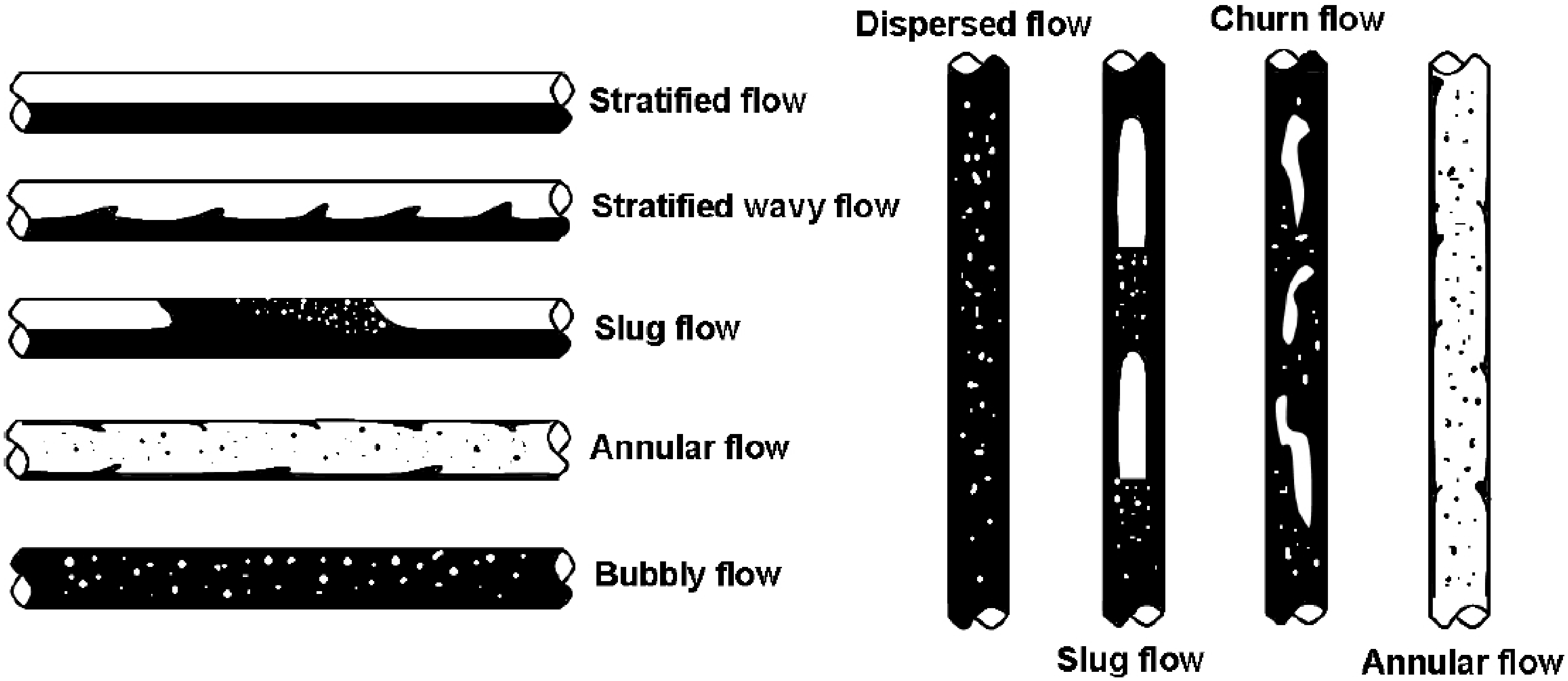
- One must know the physical properties and flowrates of the phases together with the geometry of the boundaries of the flow to calculate phase fractions and pressure losses

# Classification of multiphase flows

- Multiphase flows are classified in a number of ways

1. Firstly, flows are characterized by the number of phases present.
    - Two-phase flow, Three-phase flow etc.
2. Secondly flows are characterized by the types of phases present.
    - Gas-liquid, liquid-liquid, liquid-solid, gas-liquid-liquid etc.
3. Flows are characterized by flow patterns or *flow regimes*. Examples are:
    a) Stratified
    b) Intermittent (slug, churn, elongated bubble)
    c) Dispersed flows including (droplets, bubbles, emulsions)
    d) Annular flow
4. Finally flows can be oriented such as upward inclined, horizontal etc.

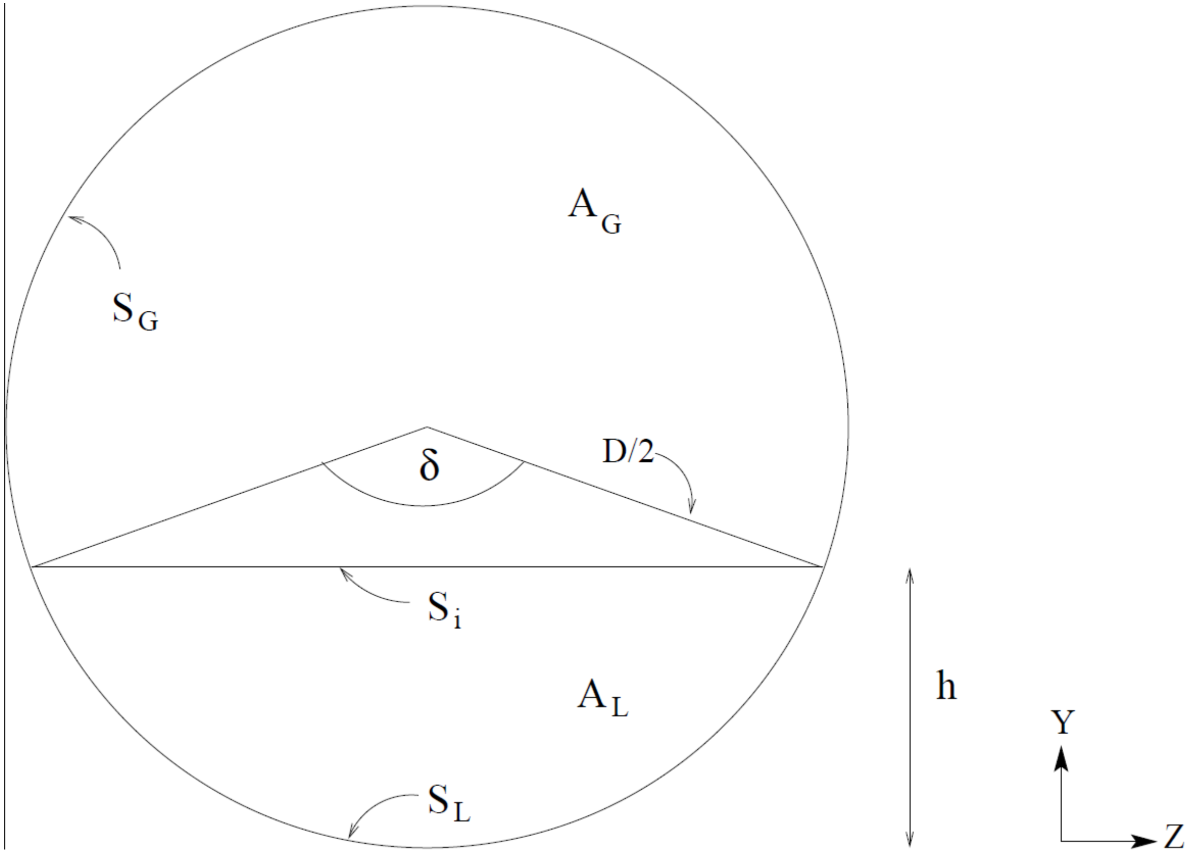
# Flow Regimes illustration



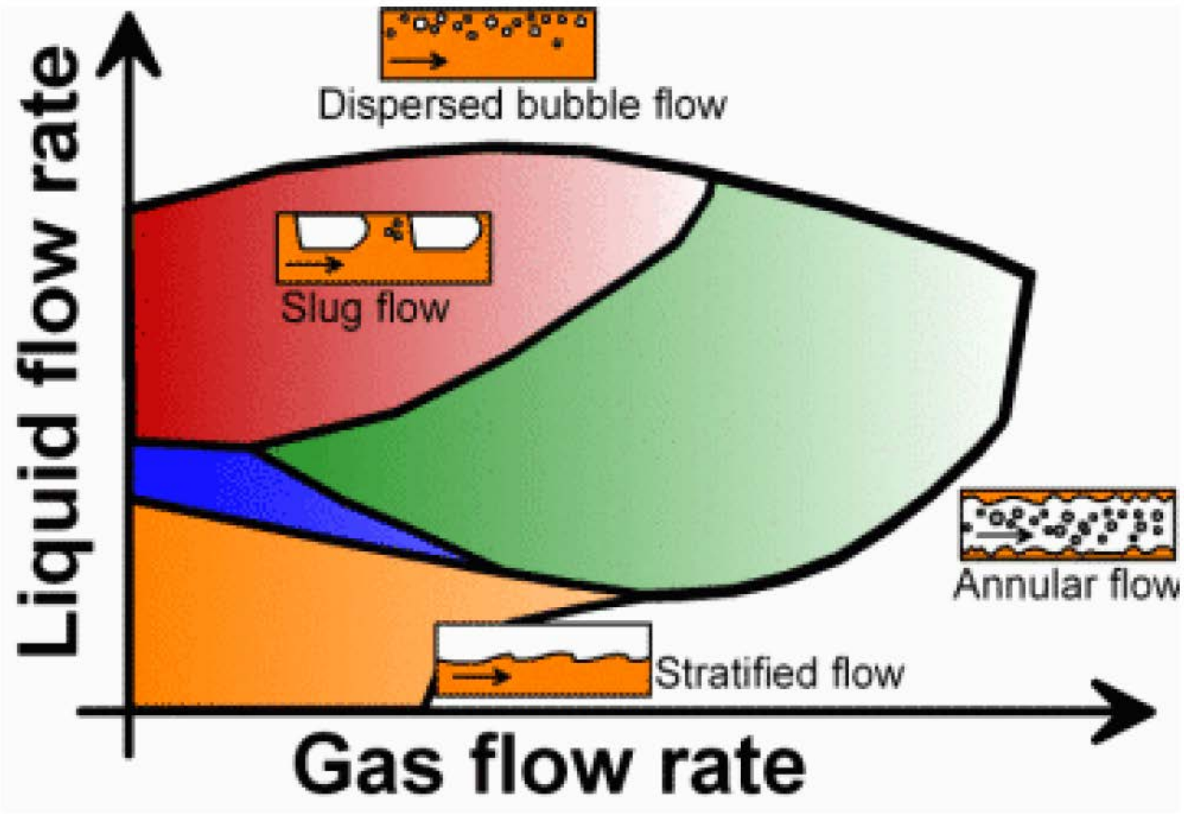
# Terminology and definitions

- In multiphase flow we specify the rate of flow using the *superficial velocity*
  - $Usl = Q_l/A$ for liquid and $Usg$=$Q_g/A$ for gas etc.
  - Where $A$ is the cross sectional area of the geometry (for example a pipe) and $Q$ is the volumetric flowrate
- The fraction of the cross section occupied by a phase is referred to as *holdup* for example liquid-holdup, gas-holdup etc.
- Liquid holdup is given by $\alpha_l = A_l/A$ where $A_l$ is the cross sectional area occupied by the liquid phase
- The in-situ *phase velocity* is defined by $U_l = Usl/\alpha\_l$
- The *slip ratio* is given by the ratio $U_s = U_g/U_l$

# Cross section of a pipe (Geometrical variables)



# Flow regime maps



# Examples of 2-phase gas-liquid stratified flow

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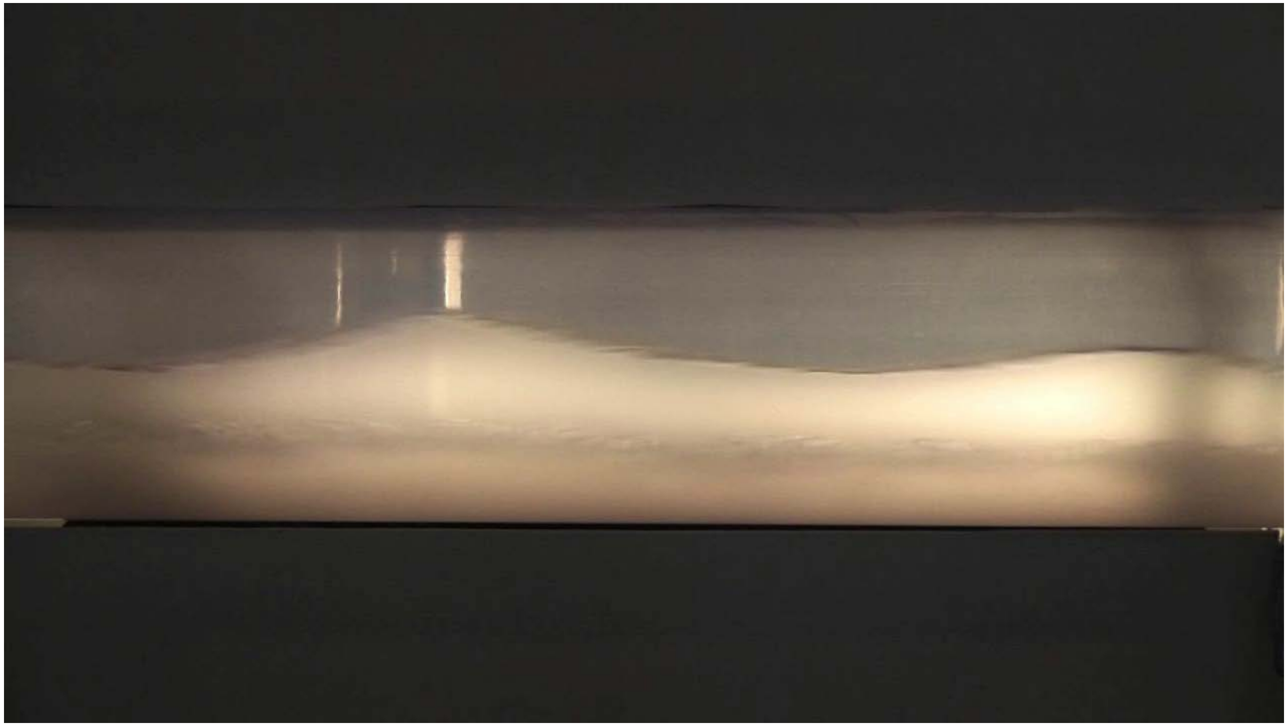
# Example 3-phase stratified flow



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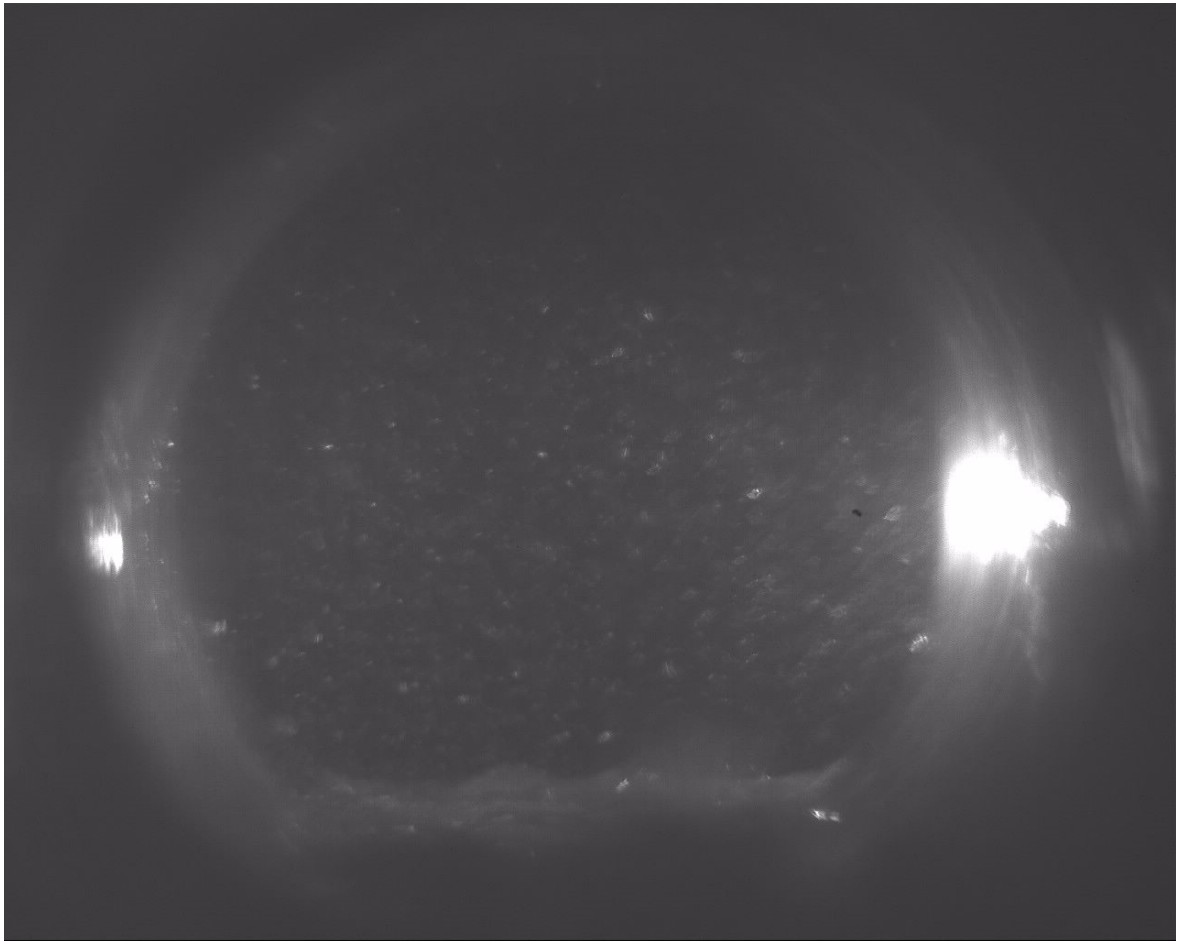
# Annular pipe flow axial view



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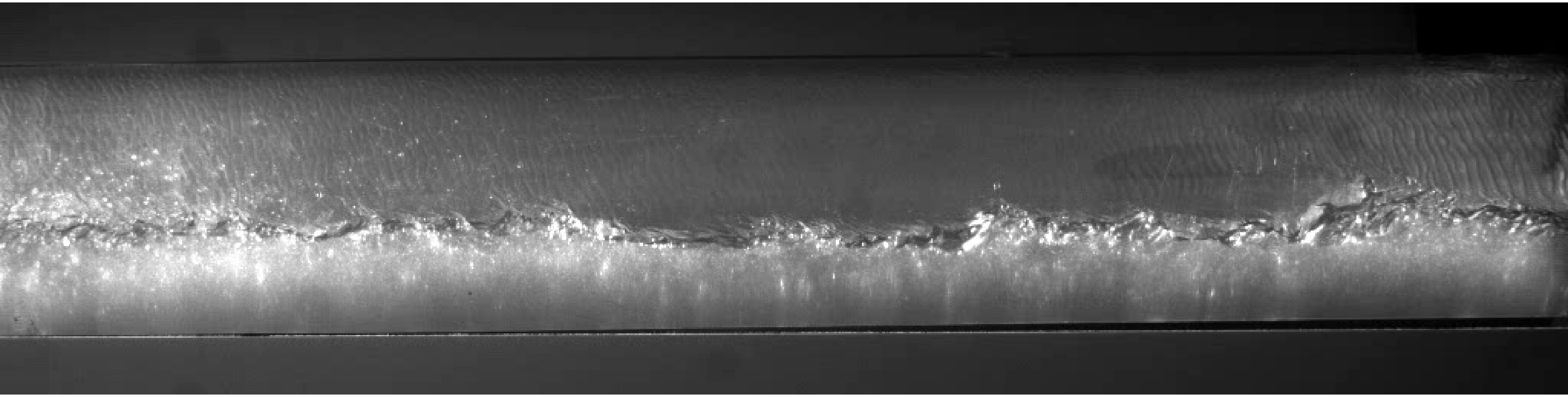
# Two-phase slug flow in an inclined pipe



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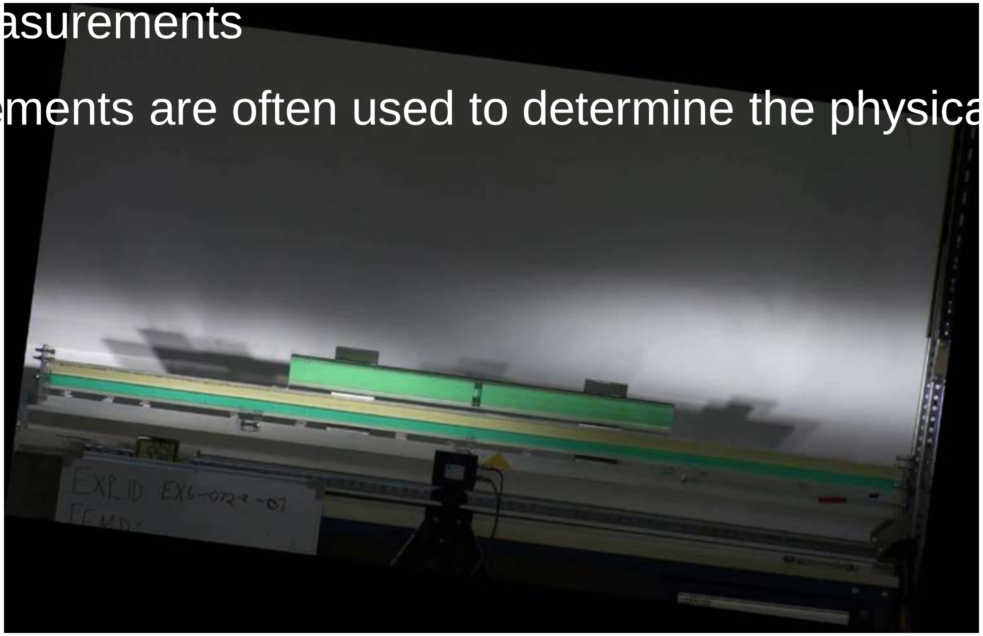
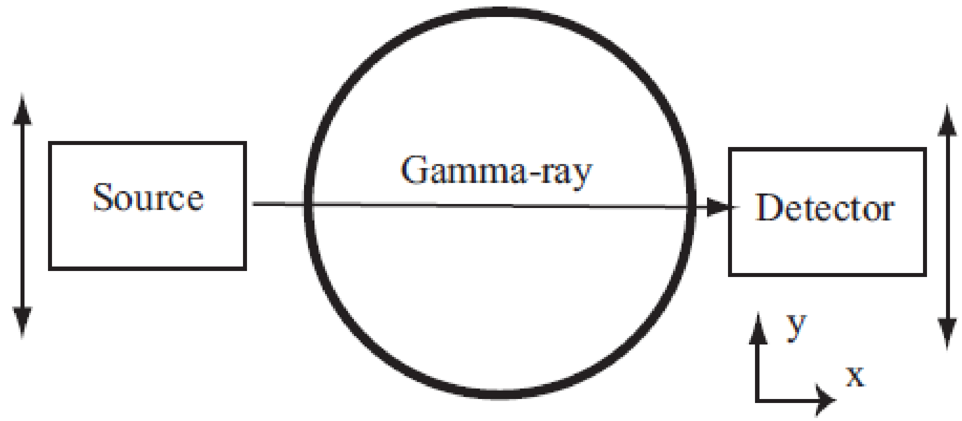
# Measurement instrumentation

- Several common types of measurements are made in multiphase flows
    1. Phase fraction measurements
    2. Pressure measurements
    3. Turbulence measurements
- Benchscale measurements are often used to determine the physical rheology of the fluids



# Phase fraction measurements

- Phase fraction measurement instrumentation must discern between the phases
- Common approaches includes
  - Conductivity
  - Capacitance
  - Gamma ray attenuation
  - Optical analysis
  - Fast closing valves



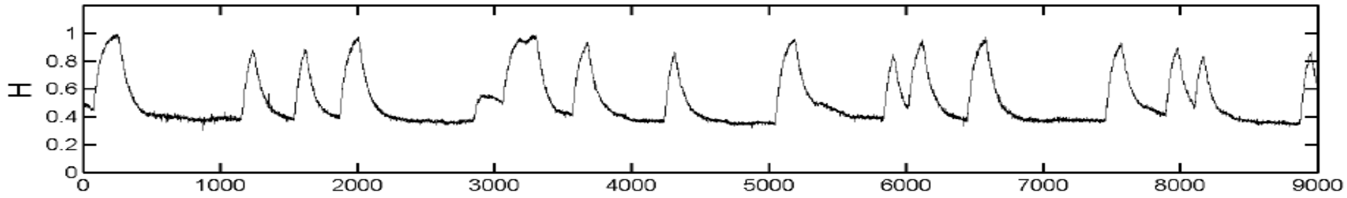




**Figure 6: $U_{sl}$ =0,50 [m/s], $U_{sg}$ =1,00 [m/s]**



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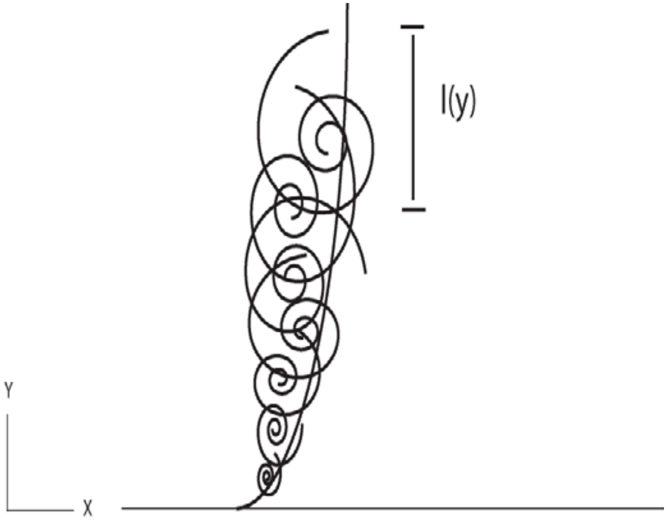
# Pressure and Turbulence measurements

- Types of pressure measurements includes
  - Absolute pressure measurements
  - Differential pressure measurements

- Turbulence measurement instrumentation includes
  - PIV (Pariticle Image Velicometry)
  - PTV (Particle Tracking Velicometry)
  - LDA (Laser Doppler Anemometry)



# Thank you

**Presentation title**

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