Modelling Batch Interfaces

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1. Background Information. Petroleum products are most economically shipped in long distance pipelines. There can be significant differences between the characteristics of the various petroleum products that are shipped, so they are shipped in batches of fluids with like characteristics. At the limits of differing characteristics are 'clean' refined products (gasoline, diesel fuel, and aviation fuels) compared to heavy crude oils that contain sulfur compounds. The owners of the products insist that cross contamination of the batches be minimized. Separation of the batches by a mechanical devise such as a pipeline pig is not practically possible.

   When the different petroleum products with different properties such as density and molecular viscosity are transported it is important to be able to distinguish the boundary between them so that upon arrival at the terminal consecutive products may be segregated into their respective tanks with a minimum of contamination. This process of segregation (or 'cutting' the stream) is made considerably more difficult when the interface between different products is tortuous with fingering of one component into the other. To reduce the effects of batch interfaces the product batches are made as large as possible so the batch interface becomes a smaller % of the entire batch. Some of the interfaces are considered as 'transmix' and must be re-refined (i.e. crude oil in gasoline). Other interfaces can be used by allowing the higher value product in the interface to be degraded (i.e. a premium gasoline/regular gasoline interface will all go to the regular gasoline tank).

   Compounding the interface mixing are the mechanical components of a pipeline. A pipeline has bends and fittings (sectionalizing valves) that disturb the flow and repumping stations (centrifugal pumps) at which the pressure is boosted at approximately 50 mile intervals.

   If it were possible to calculate batch interfaces, or even to better understand which parameters determine their growth rate it may be possible to optimize batch shipments by reducing the product degradation. This would have a considerable economic impact on petroleum pricing. As a side issue of this problem is the cost of shipping through a pipeline when the drag coefficient is larger than need be.

2. Statement of the problems. The purpose of the workshop is to explore the mechanisms by which the bi-fluid vertical interface deforms with time when these two fluids flow through a pipe of cylindrical geometry under the driving force of a constant pressure gradient. These differing fluids may have different viscosity or different densities or both. Obviously the case of differing densities will be considerably more difficult because the flow will lose cylindrical symmetry due to the influence of gravity producing negative buoyancy effects

3. Physics. The flow with both properties different will behave like a combination of a Poiseuille flow modified by gravity-current-like behaviour. That is the current will lose

symmetry as the heavier fluid moves down the side of the container and under the lighter fluid.

4. Fluids Properties. Consider that any combination of these fluids could be shipped or batches with any other (head to tail):

Material	Density (km/m^3)	Viscosity (centistokes at 15 C)
NGL	560	0.1
Gasoline	700	0.4
Diesel Fuel	800	0.9
Synthetic Crude	585	5.5
Condensate	672	0.5
Sweet Lights	830	6
Sour Lights	852	15
Medium Crude	886	55
Heavy Crude	920	170

5. Empirical Information. Pipeline companies have developed means to cope with the problem. Firstly all the pipeline flows are fully turbulent, and pipeline start-up precedures have been developed that quickly take the flow through the laminar region. Typically the flow speed is 5 mph and Reynolds numbers are a minimum of 4000. Batch interfaces tend to stabilize in a 20" pipeline at about 250 m3. A 20" or 24" pipeline is a good size to consider