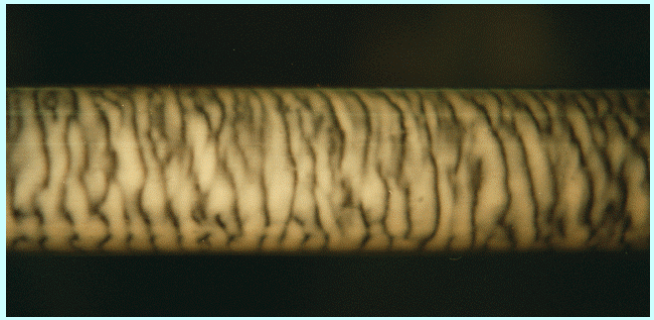
Water Lubricated Pipelining of Viscous Crudes

- Joseph and his team (DOE/BES supported since 1987) pioneered the method of water-lubricated pipelining of heavy crudes (US patent 5988198, 11/23/99)
  - Water lubricates the flow leading to drag reductions of the order of the viscosity ratio, 10^4 or more
  - Established conditions for stability, rules for scaling up test results from small diameter pipes to large diameter pipes used on oil fields
  - Pressure scales with the ratio $U^{7/4} / R_o^{5/4}$, where U is viscosity and R_o is pipe radius



Milky clay water separated by 'tiger waves' aid in lubrication

- Bitumen froth in Alberta is used to prepare high quality sweet crude
  - Froth self-lubricates when pipelined at speeds greater than critical
  - Emulsion breaks at the pipe wall and lubricating films of clay water are formed
  - Clay protects the oil from sticking to itself like powder on dough
- Syncrude Canada invested $76 million in a 36" pipeline to transport self-lubricated froth 35 km for upgrading (start August 2000)
- Major US oil companies are studying lubricated pipelining with Joseph's team
- Joseph was elected to National Academies of Sciences, of Engineering, of Art & Sciences and other awards. He was the recipient of the 1999 Fluid Dynamics Prize "in recognition of the broad range of his contributions to the stability and bifurcation of fluid flows, rheological fluid mechanics and fluid mechanics of problems involving solid-liquid boundaries."

Syncrude/2000/lubrication

R. Bai & D.D. Joseph next to the 24 in. Pipeline Pilot at the Oil Sands in Fort McMurray

Syncrude/2000/lubrication

Water Lubricated Pipelining of Viscous Crudes

Heavy oils are too viscous to transport economically in pipelines. Joseph's team has pioneered the method of water lubricated pipelining of heavy crudes; the water goes to the wall and lubricates the flow leading to drag reductions of the order of the viscosity ratio, ten thousand or more. They established the conditions for stability of lubricating water layer and the rules for scaling up test results from small diameter pipes used in lab studies to large diameter pipes used on the oil fields; the pressure scales with the ratio U 7/4 / Ro 5/4, where U is viscosity and Ro is the pipe radius.

Bitumen froth from oil sands in Alberta is an emulsion of colloidal clay water used to prepare high quality sweet crude. Joseph's team showed that the froth self-lubricates when pipelined at speeds greater than critical; the emulsion breaks at the pipe wall and lubricating films of clay water are formed; clay protects the oil

from sticking to itself like powder on dough; the milky clay water separated by "tiger waves", which aid lubrication, are shown in the figure.

Using Joseph's reliability and scale-up studies, Syncrude Canada has invested 76 million dollars in a 36" pipeline to transport self-lubricated froth 35 kilometers for upgrading; the line will start to transport froth in August 2000. US major oil companies are studying the lubricated pipelining with Joseph's team. Joseph's work on lubricated transport has been supported by DOE/BES since 1987. Since that time Joseph was elected to the National Academy of Sciences, Engineering, to the National Academy of Art and Sciences, and received many other awards. He was the recipient of the 1999 Fluid Dynamics Prize of the American Physical Society "in recognition of the broad range of his contributions to the stability and bifurcation of fluid flows, rheological fluid mechanics and fluid mechanics of problems involving solid-liquid boundaries."