Optimizing Life Cycle Pipeline Costs

for

A Private Client

May 16, 2011

By

Pipeline Knowledge & Development

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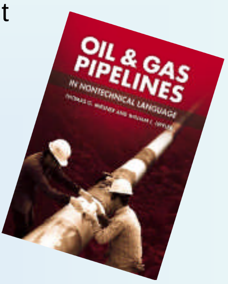
Instructor – Tom Miesner



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  - Strategy and Project Development
  - Expert Testimony and Arbitration
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- 7 years pipeline consulting
- 24 years with Conoco Pipe Line Company
- Author *Oil and Gas Pipelines in NonTechnical Language,The Role of Pipelines and Research in the U. S., Pipeline Engineering for McGraw Hill, and* various articles and reports
- Currently writing, *The Final Mile, Natural Gas Distribution Pipelines in NonTechnical Language*
- Produced and teach 18 pipeline related training modules and the two day Oil and Gas Pipeline Fundamentals class

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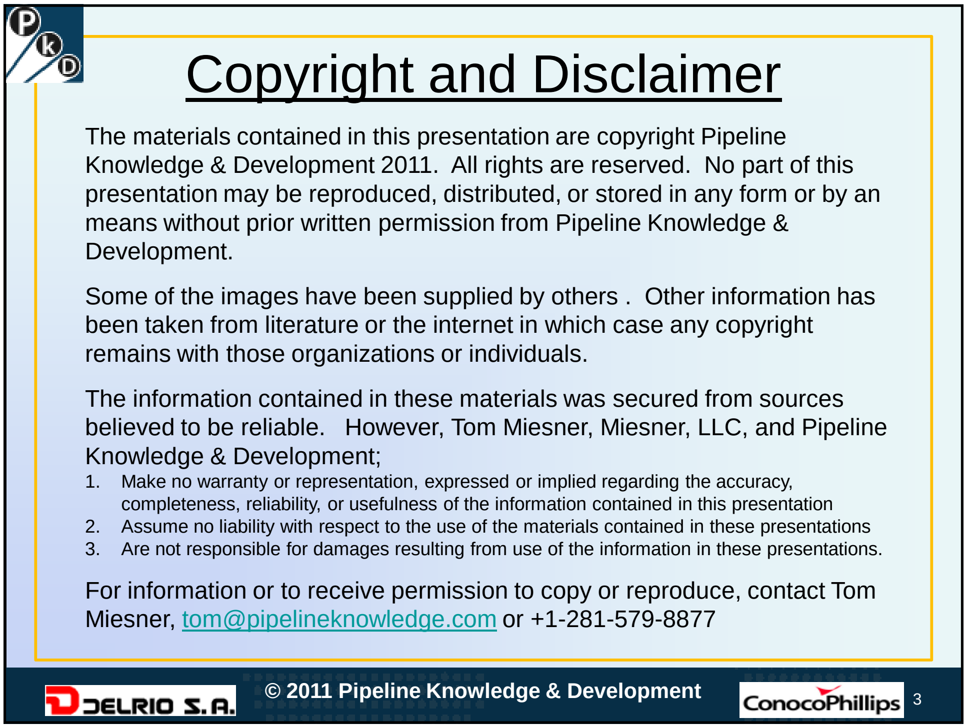

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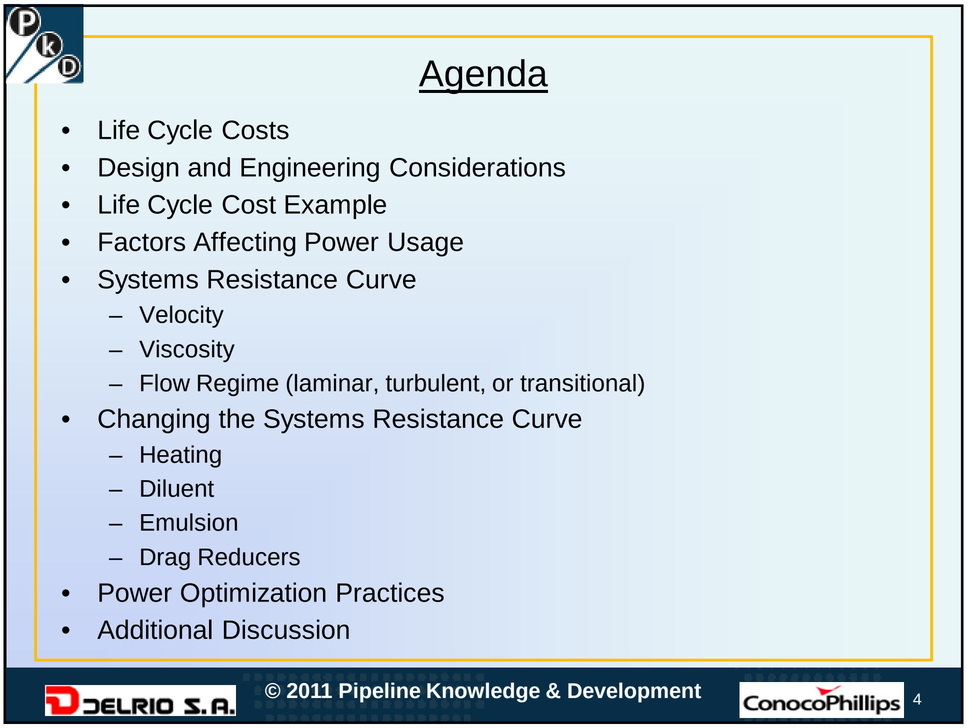

Agenda

- Life Cycle Costs
- Design and Engineering Considerations
- Life Cycle Cost Example
- Factors Affecting Power Usage
- Systems Resistance Curve
  - Velocity
  - Viscosity
  - Flow Regime (laminar, turbulent, or transitional)
- Changing the Systems Resistance Curve
  - Heating
  - Diluent
  - Emulsion
  - Drag Reducers
- Power Optimization Practices
- Additional Discussion

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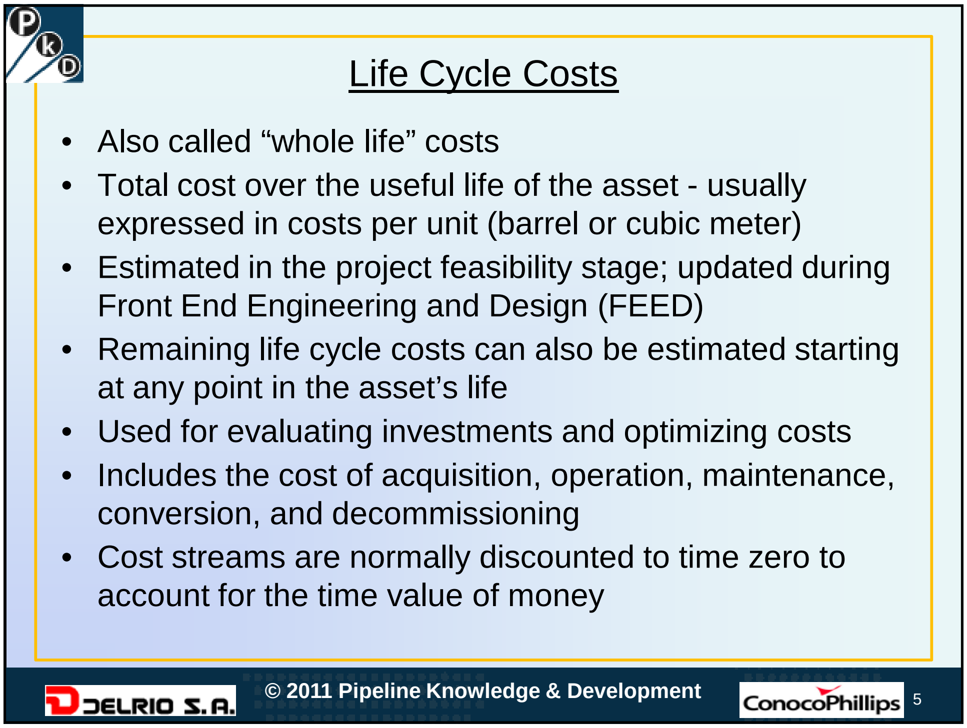

Life Cycle Costs

- Also called “whole life” costs
- Total cost over the useful life of the asset - usually expressed in costs per unit (barrel or cubic meter)
- Estimated in the project feasibility stage; updated during Front End Engineering and Design (FEED)
- Remaining life cycle costs can also be estimated starting at any point in the asset’s life
- Used for evaluating investments and optimizing costs
- Includes the cost of acquisition, operation, maintenance, conversion, and decommissioning
- Cost streams are normally discounted to time zero to account for the time value of money

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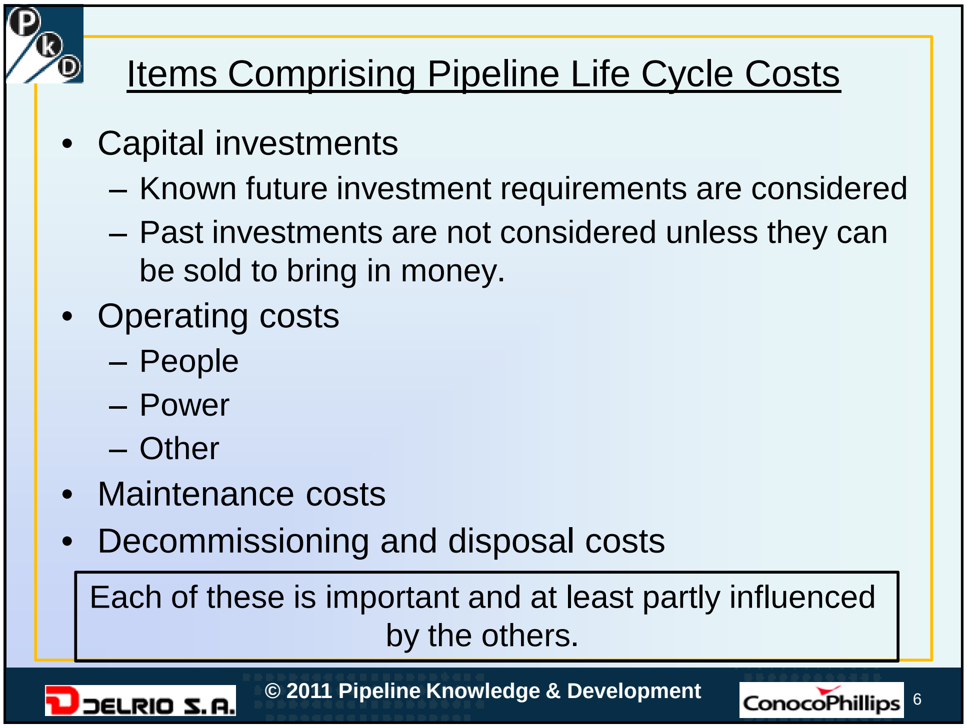

Items Comprising Pipeline Life Cycle Costs

- Capital investments
  - Known future investment requirements are considered
  - Past investments are not considered unless they can be sold to bring in money.
- Operating costs
  - People
  - Power
  - Other
- Maintenance costs
- Decommissioning and disposal costs

Each of these is important and at least partly influenced by the others.

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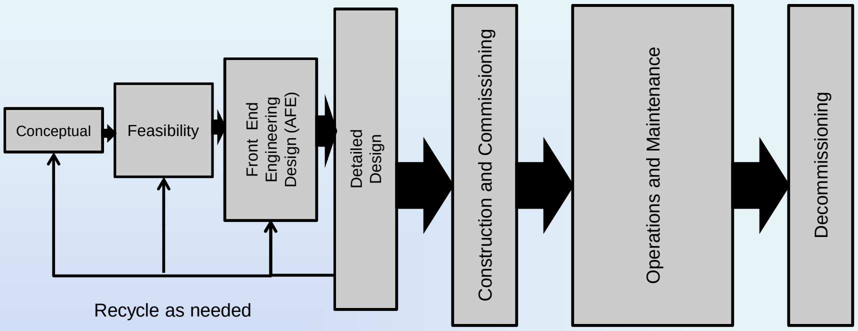
The Project Life Cycle



The entire spectrum must be considered

Courtesy Pipeline Knowledge & Development – Introduction to Engineering

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Design Basis Document Contains the Parameters

- Design capacity (flow rate where design is to optimized)
- Operating range (range of expected flow rates)
- Fluid properties (density, viscosity, specific heat)
- Operating temperature range
- Applicable codes and standards
- Process control philosophy
- Preliminary route receipt and delivery locations
- Sensitivities regarding customers, regulators, public opinion, geological, environmental, or other considerations which would affect line design or routing,
- Project economics and economic sensitivities
- Special operating considerations

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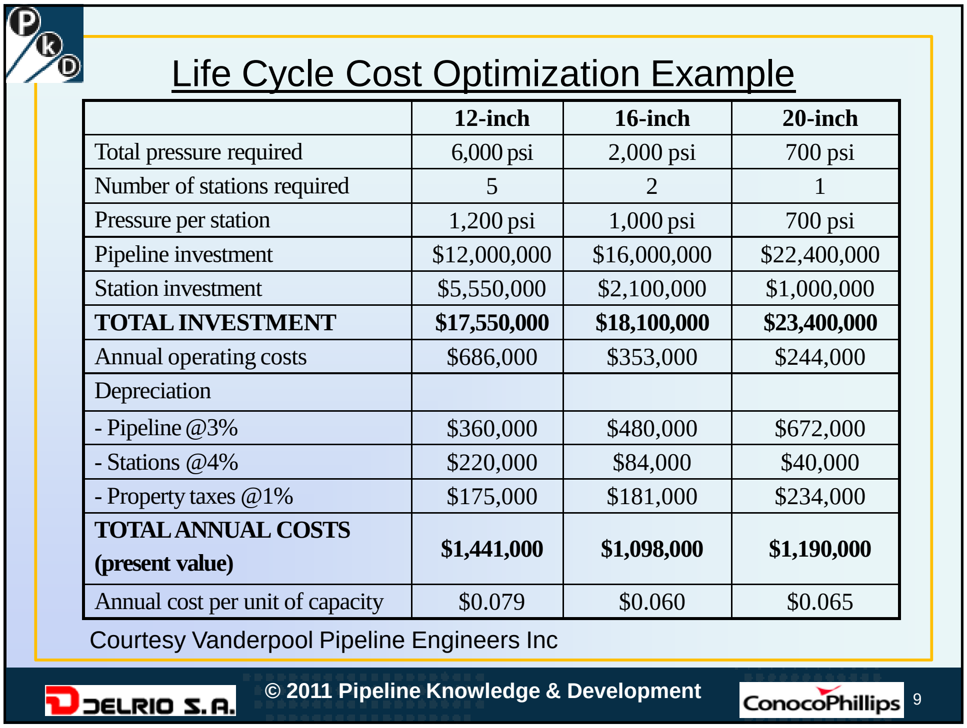

Life Cycle Cost Optimization Example

	12-inch	**16-inch**	**20-inch**
Total pressure required	6,000 psi	2,000 psi	700 psi
Number of stations required	5	2	1
Pressure per station	1,200 psi	1,000 psi	700 psi
Pipeline investment	$12,000,000	$16,000,000	$22,400,000
Station investment	$5,550,000	$2,100,000	$1,000,000
TOTAL INVESTMENT	**$17,550,000**	**$18,100,000**	**$23,400,000**
Annual operating costs	$686,000	$353,000	$244,000
Depreciation			
- Pipeline @3%	$360,000	$480,000	$672,000
- Stations @4%	$220,000	$84,000	$40,000
- Property taxes @1%	$175,000	$181,000	$234,000
TOTAL ANNUAL COSTS (present value)	**$1,441,000**	**$1,098,000**	**$1,190,000**
Annual cost per unit of capacity	$0.079	$0.060	$0.065

Courtesy Vanderpool Pipeline Engineers Inc

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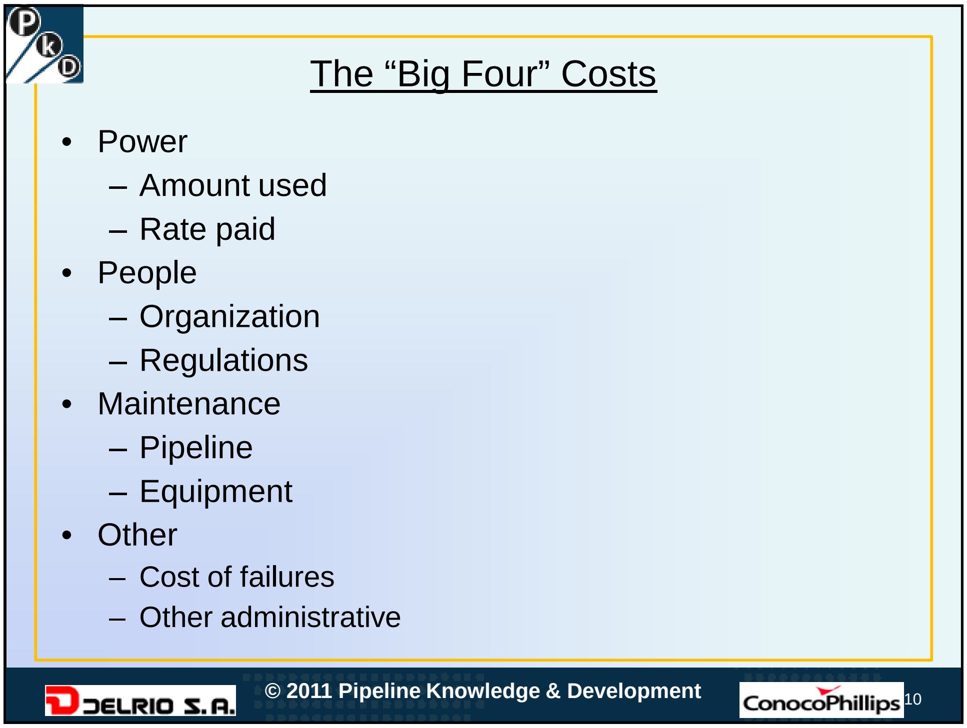

The “Big Four” Costs

- Power
  - Amount used
  - Rate paid
- People
  - Organization
  - Regulations
- Maintenance
  - Pipeline
  - Equipment
- Other
  - Cost of failures
  - Other administrative

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Factors Affecting Power Usage

- Absolute elevation change between points;
- Fluid characteristics
  - density
  - viscosity
- Velocity
- Pipeline
  - Length
  - Diameter
  - Internal pipe roughness
- Configuration of pump and other stations
- Operating practices
- Equipment efficiency

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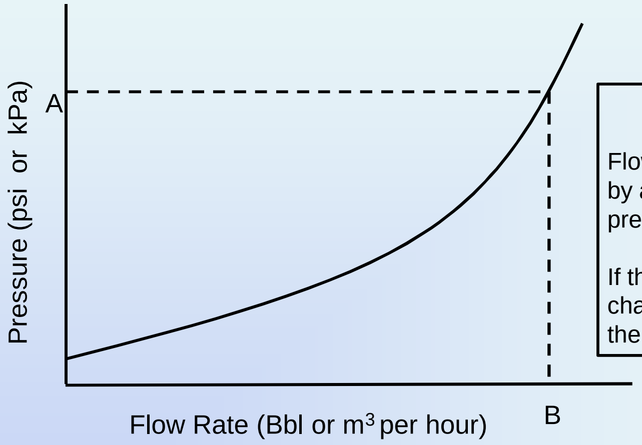
A Tool – The Systems Resistance Curve



Systems Curve

Flow rate achieved by applying various pressures to a system.

If the system or fluid changes, so does the curve.

The systems resistance curve is key to optimizing power

Courtesy Pipeline Knowledge & Development – Introduction to Hydraulics

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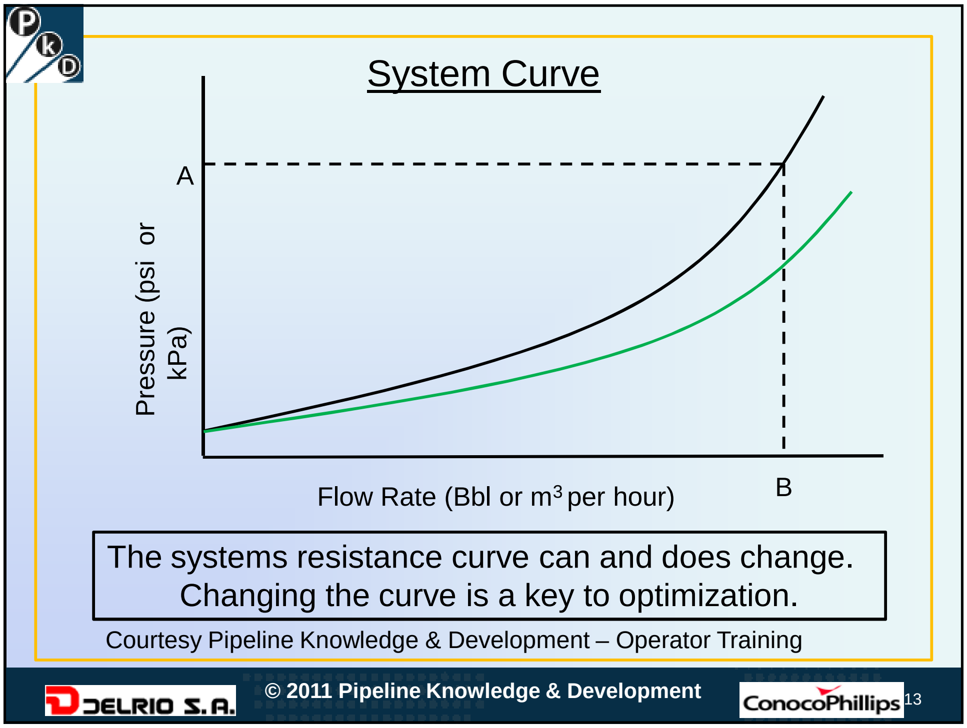

System Curve

The systems resistance curve can and does change. Changing the curve is a key to optimization.

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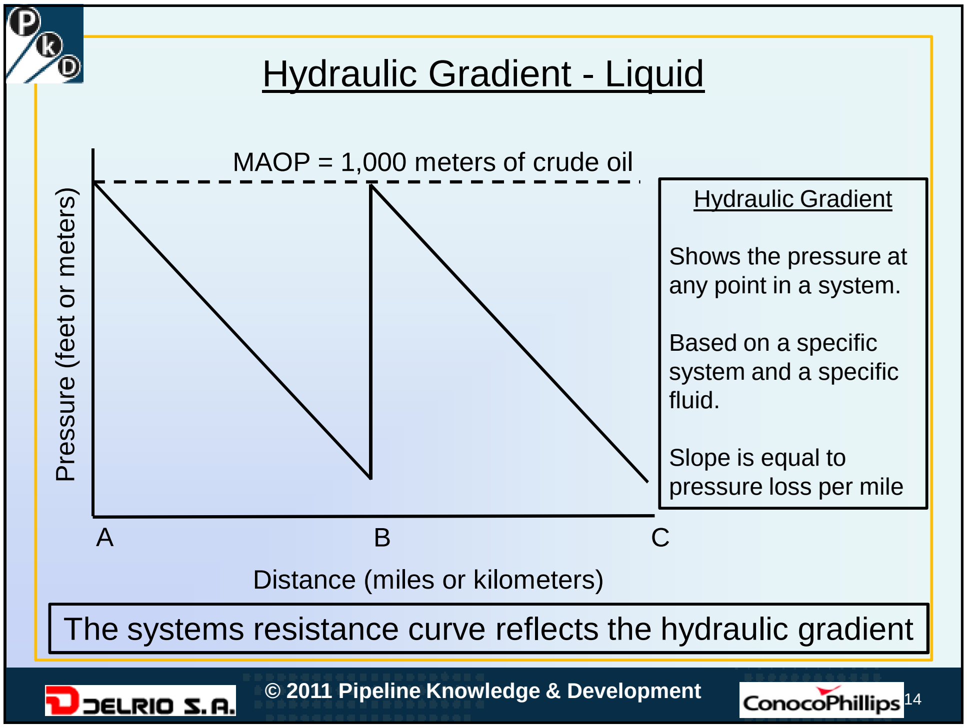

Hydraulic Gradient - Liquid

Hydraulic Gradient

Shows the pressure at any point in a system.

Based on a specific system and a specific fluid.

Slope is equal to pressure loss per mile

The systems resistance curve reflects the hydraulic gradient

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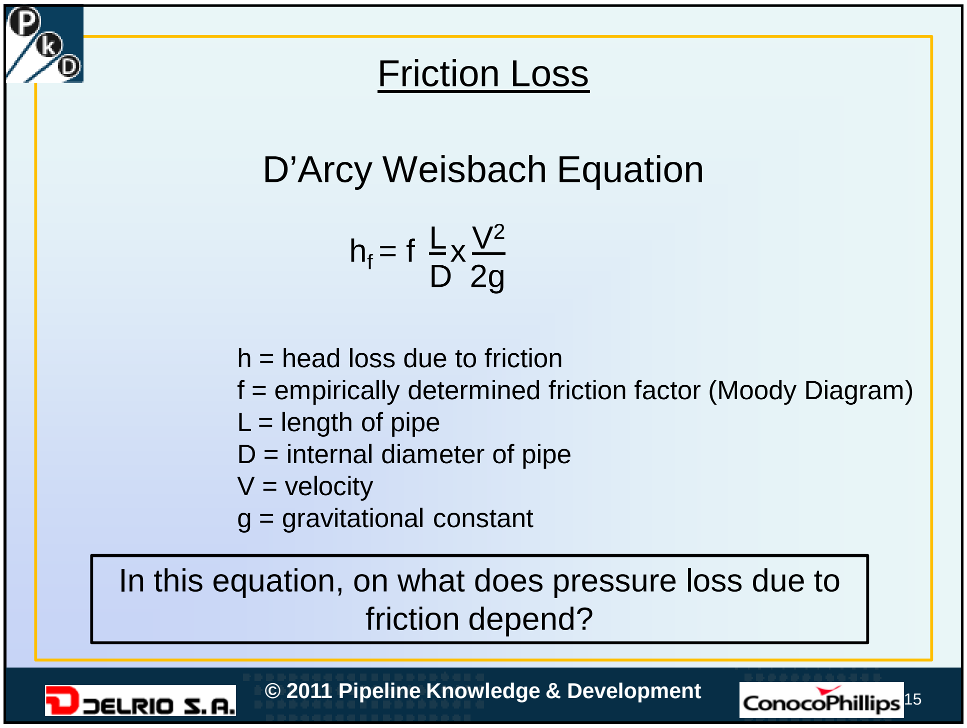

Friction Loss

D'Arcy Weisbach Equation

$$h_f = f \frac{L}{D} x \frac{V^2}{2g}$$

h = head loss due to friction
f = empirically determined friction factor (Moody Diagram)
L = length of pipe
D = internal diameter of pipe
V = velocity
g = gravitational constant

In this equation, on what does pressure loss due to friction depend?

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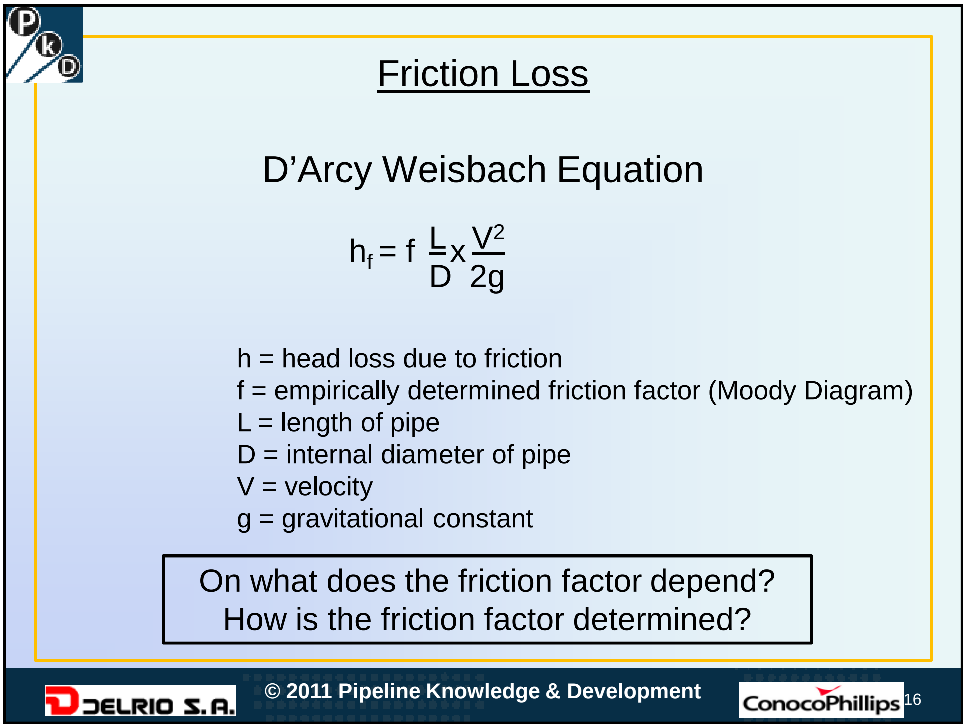

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h = head loss due to friction
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L = length of pipe
D = internal diameter of pipe
V = velocity
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On what does the friction factor depend?
How is the friction factor determined?

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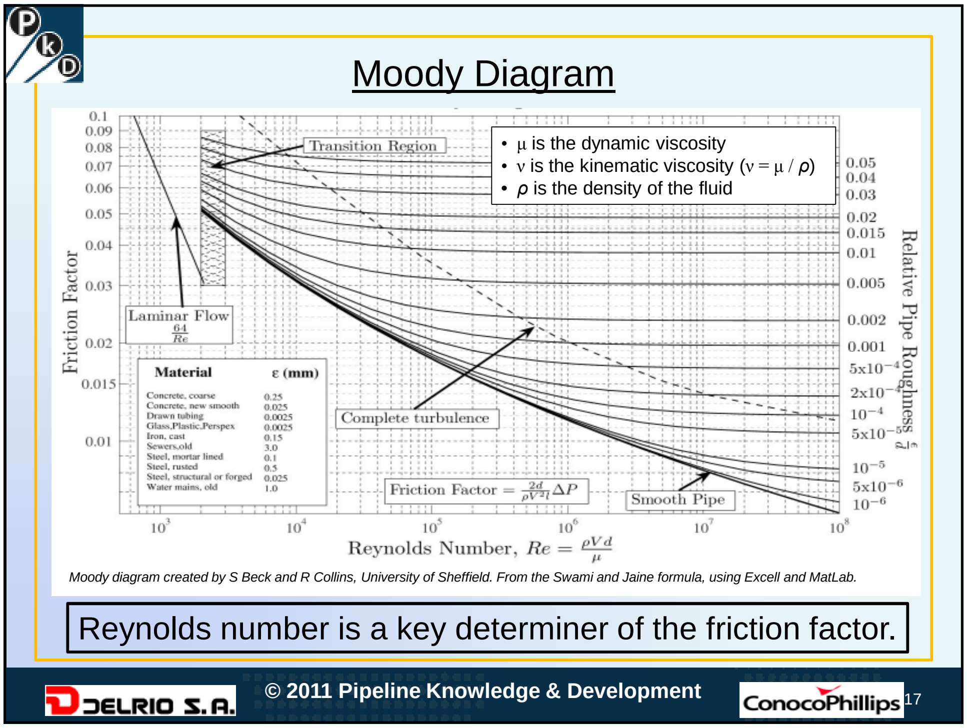

Moody Diagram

- μ is the dynamic viscosity
- ν is the kinematic viscosity (ν = μ / ρ)
- ρ is the density of the fluid

Material	ε (mm)
Concrete, coarse	0.25
Concrete, new smooth	0.025
Drawn tubing	0.0025
Glass,Plastic,Perspex	0.0025
Iron, cast	0.15
Sewers,old	3.0
Steel, mortar lined	0.1
Steel, rusted	0.5
Steel, structural or forged	0.025
Water mains, old	1.0

Moody diagram created by S Beck and R Collins, University of Sheffield. From the Swami and Jaine formula, using Excell and MatLab.

Reynolds number is a key determiner of the friction factor.

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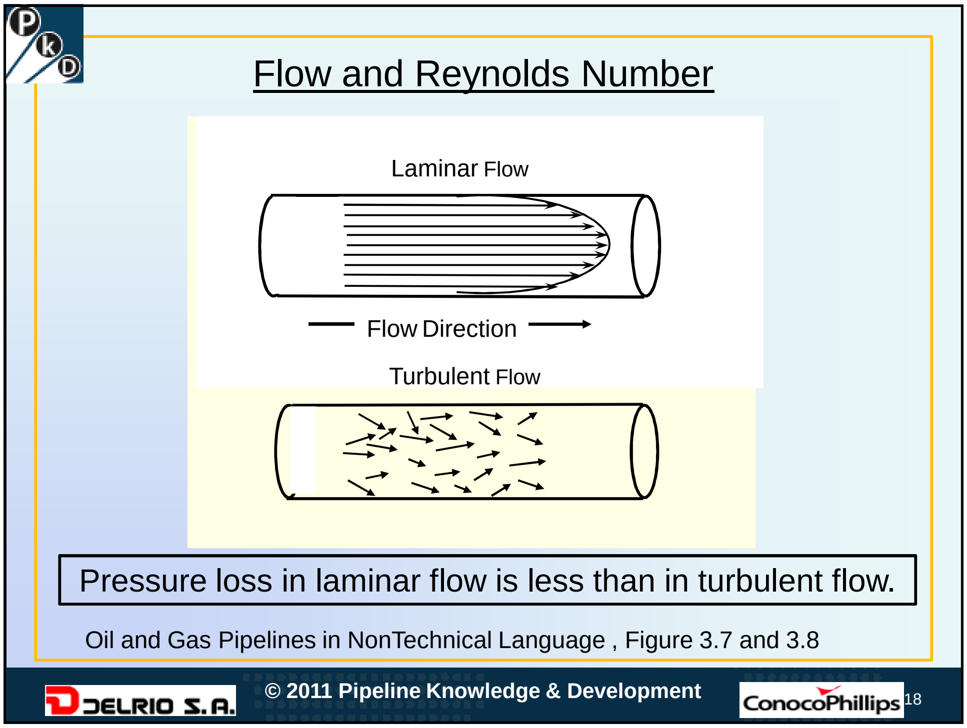

Flow and Reynolds Number

Pressure loss in laminar flow is less than in turbulent flow.

Oil and Gas Pipelines in NonTechnical Language , Figure 3.7 and 3.8

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Calculating the Reynolds Number

$$\text{Reynolds Number} = \frac{\text{Density X Velocity X Diameter}}{\text{Dynamic Viscosity}}$$

$$\text{Kinematic Viscosity} = \frac{\text{Dynamic Viscosity}}{\text{Density}}$$

$$\text{Reynolds Number} = \frac{\text{Velocity X Diameter}}{\text{Kinematic Viscosity}}$$

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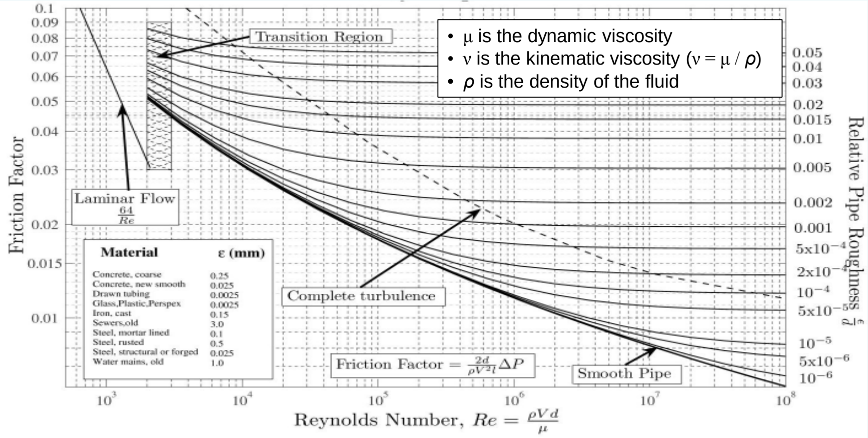
Moody Diagram



- μ is the dynamic viscosity
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Moody diagram created by S Beck and R Collins, University of Sheffield. From the Swami and Jaine formula, using Excell and MatLab.

Extending Laminar (transition) flow results in lower pressure loss

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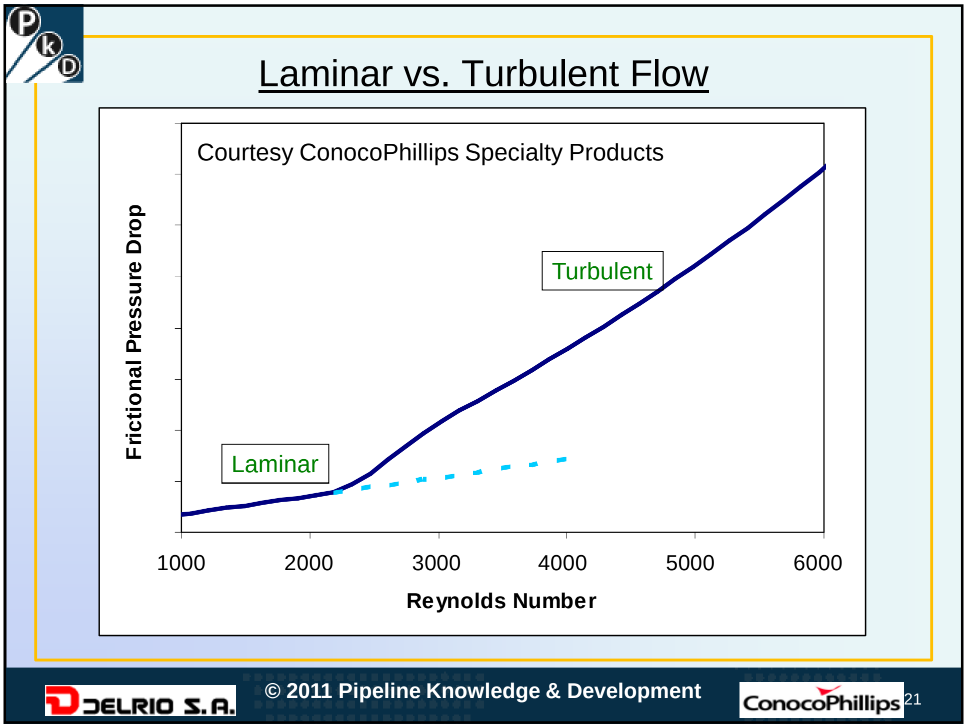

Laminar vs. Turbulent Flow

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Items which Impact Friction Loss Per Mile

- Fluid characteristics
  - Viscosity
  - Density
- Flow rate
  - Diameter
  - Volume
  - Blend ratios
- Friction factor
  - Internal roughness
  - Reynolds number

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Ways to Change the Systems Curve

- Velocity
  - Flow rate (lower velocity means less friction loss)
  - Scheduling (consistent flow rate saves energy)
  - Diameter (larger diameter results in lower velocity)
- Viscosity/density
  - Heating
  - Diluent
  - Emulsions
  - Chemicals
- Control valves vs. variable speed drives

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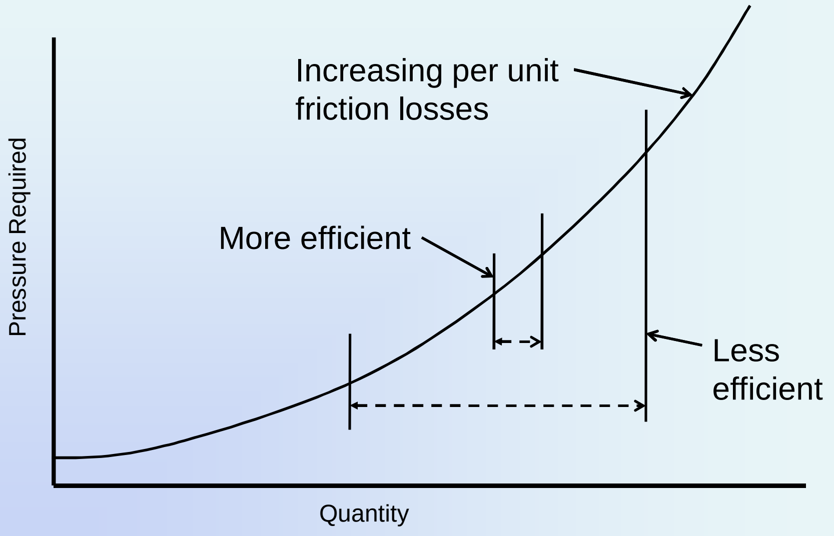
Efficient Scheduling



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Heading

Objective – reduce viscosity to improve flow rate or reduce energy required to pump.

Items to consider

- Cost and space required for heating equipment
- Cost of energy to heat the oil (units required, rate paid)
- Elevated versus buried (visual, ease of transit)
- Effect on the environment (emissions, subsoil, visual)
- Insulation (insulating properties, temperature limits)
- Cooling factors (ambient conditions, water table)

Heating is more common in short lines than in long lines.

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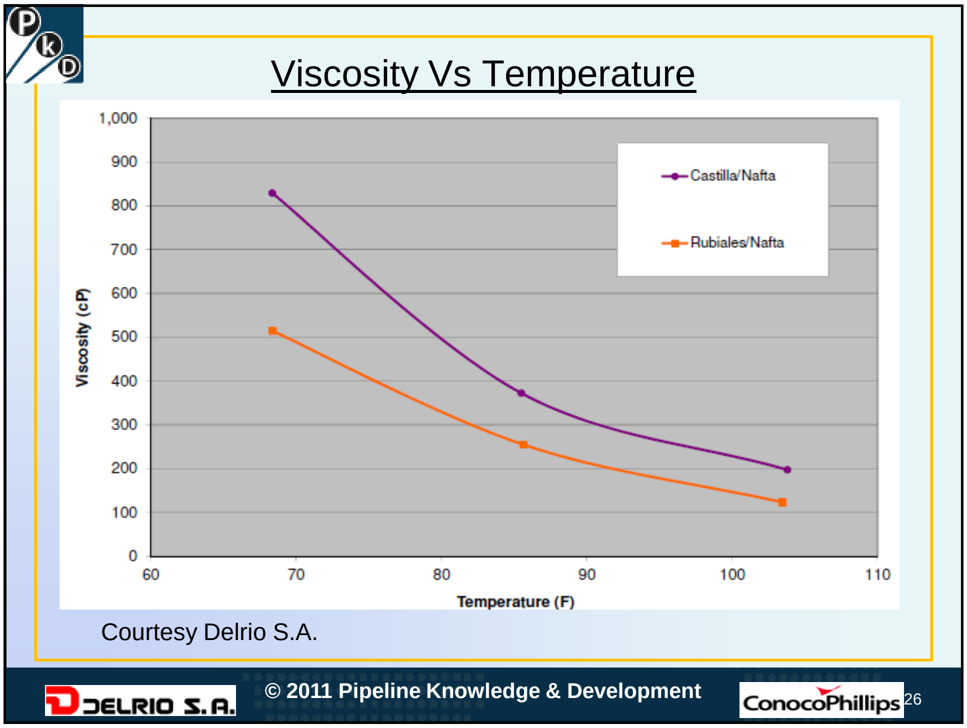

Viscosity Vs Temperature

Courtesy Delrio S.A.

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Diluent

Blend a lighter hydrocarbon with the crude oil to reduce viscosity thereby increasing flow rate and/or reducing energy required to pump the crude oil.

Items to consider

- Cost and space for blending and separation equipment
- Type of diluent (condensate, light crude, other)
- Amount required (viscosity effect, logistics)
- Logistics (origin, destination)
- Cost (purchase, transportation)
- Total pumping costs (crude oil plus diluent)
- Net versus gross gain

Diluent blending is a common strategy

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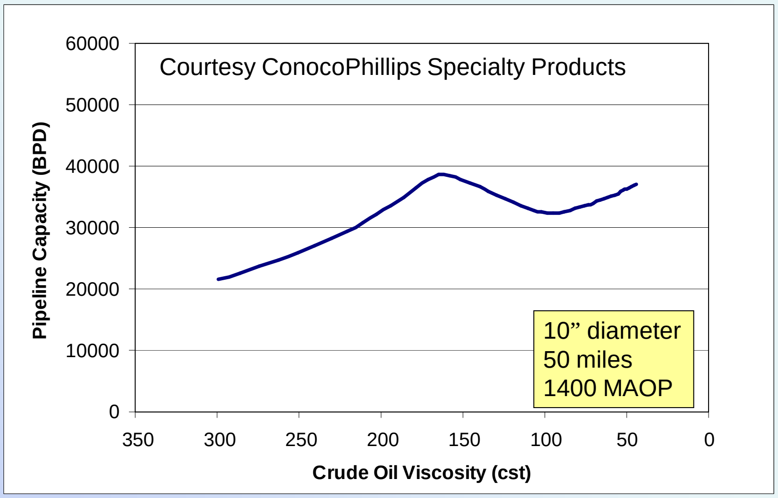
Diluent to Improve Capacity



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10” diameter
50 miles
1400 MAOP

Too much diluent can move the system into transition flow reducing capacity

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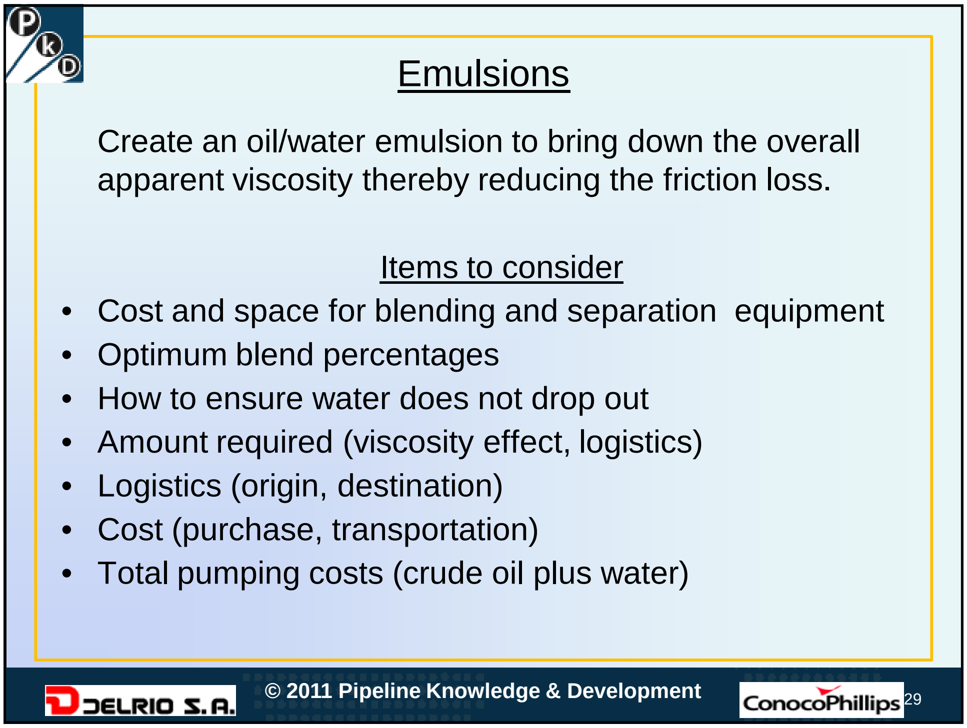

Emulsions

Create an oil/water emulsion to bring down the overall apparent viscosity thereby reducing the friction loss.

Items to consider

- Cost and space for blending and separation equipment
- Optimum blend percentages
- How to ensure water does not drop out
- Amount required (viscosity effect, logistics)
- Logistics (origin, destination)
- Cost (purchase, transportation)
- Total pumping costs (crude oil plus water)

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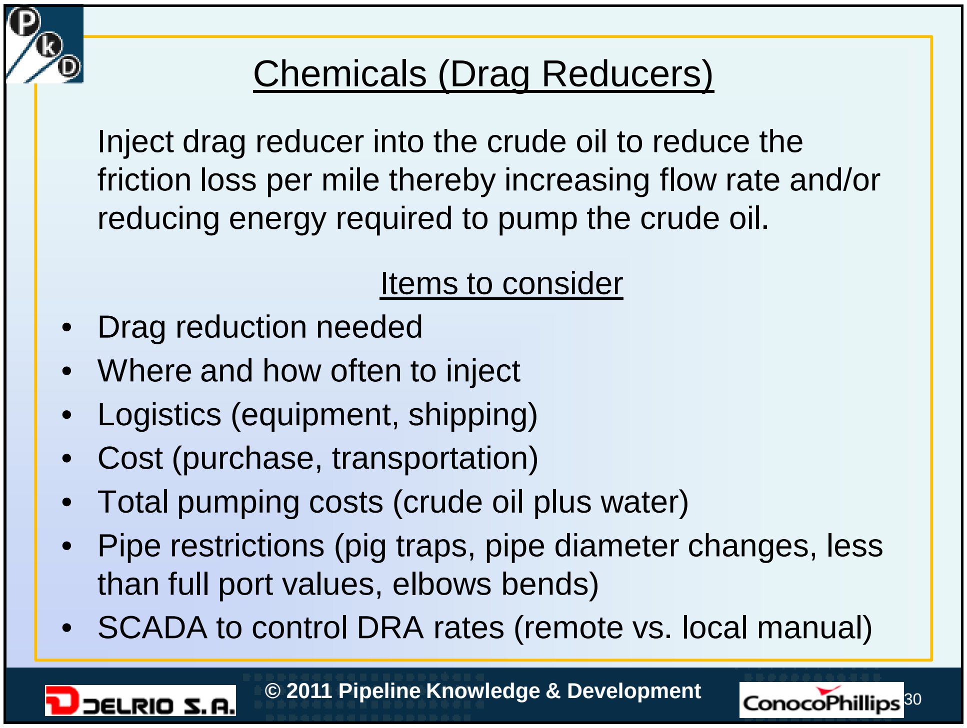

Chemicals (Drag Reducers)

Inject drag reducer into the crude oil to reduce the friction loss per mile thereby increasing flow rate and/or reducing energy required to pump the crude oil.

Items to consider

- Drag reduction needed
- Where and how often to inject
- Logistics (equipment, shipping)
- Cost (purchase, transportation)
- Total pumping costs (crude oil plus water)
- Pipe restrictions (pig traps, pipe diameter changes, less than full port values, elbows bends)
- SCADA to control DRA rates (remote vs. local manual)

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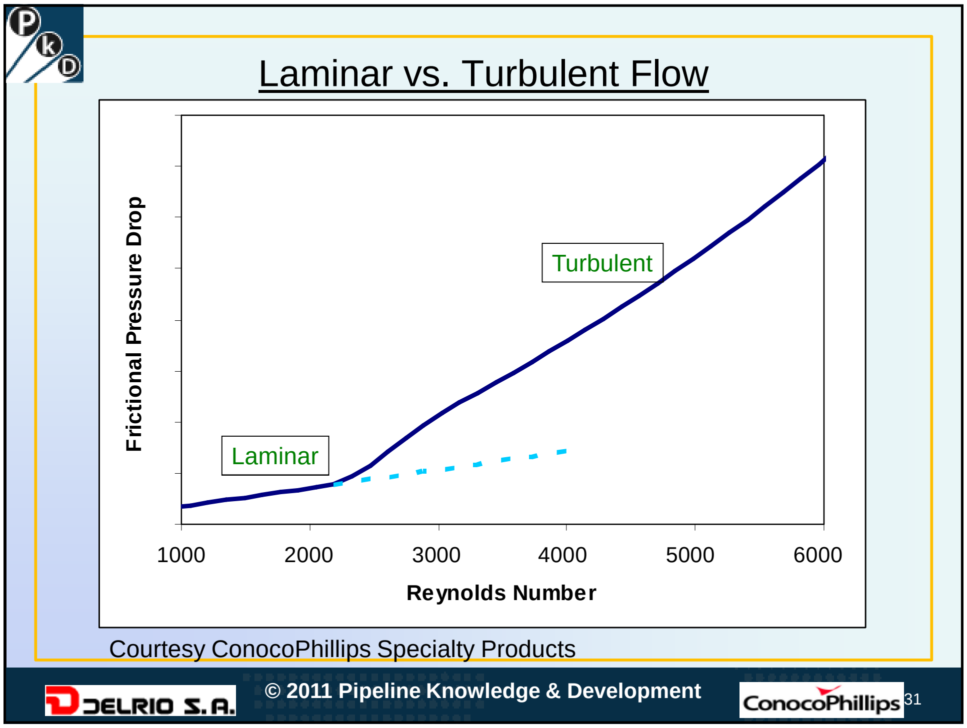

Laminar vs. Turbulent Flow

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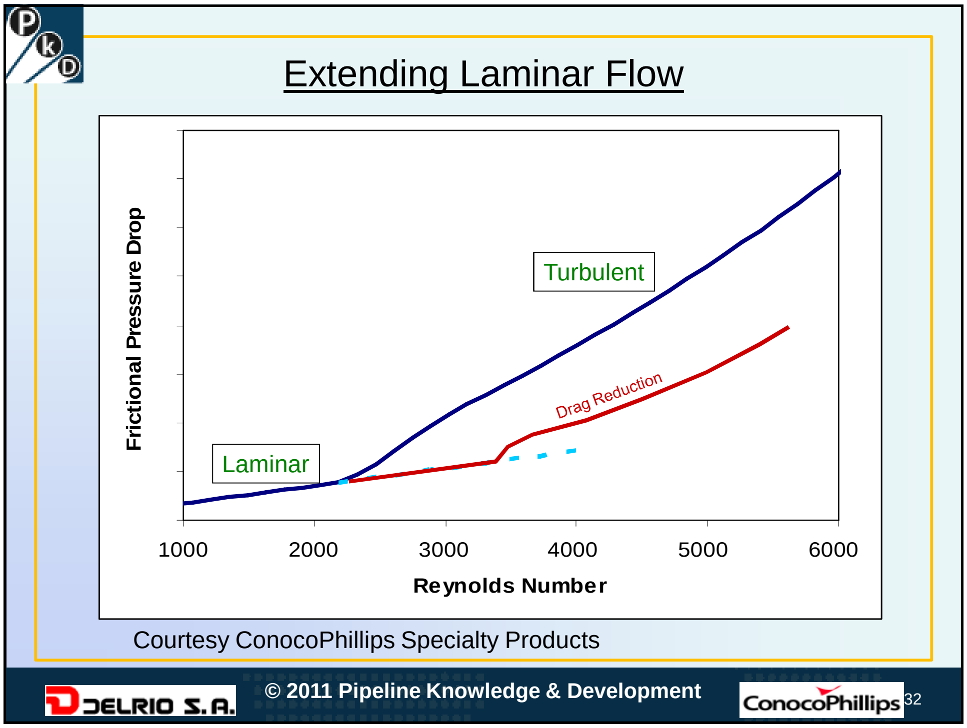

Extending Laminar Flow

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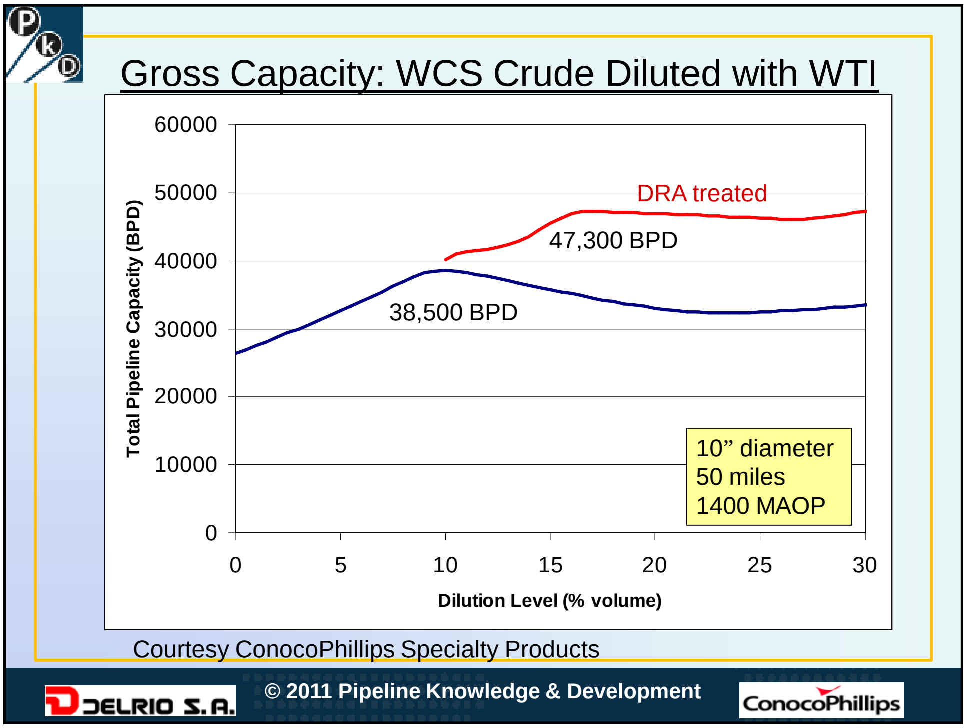

Gross Capacity: WCS Crude Diluted with WTI

10” diameter
50 miles
1400 MAOP

Courtesy ConocoPhillips Specialty Products

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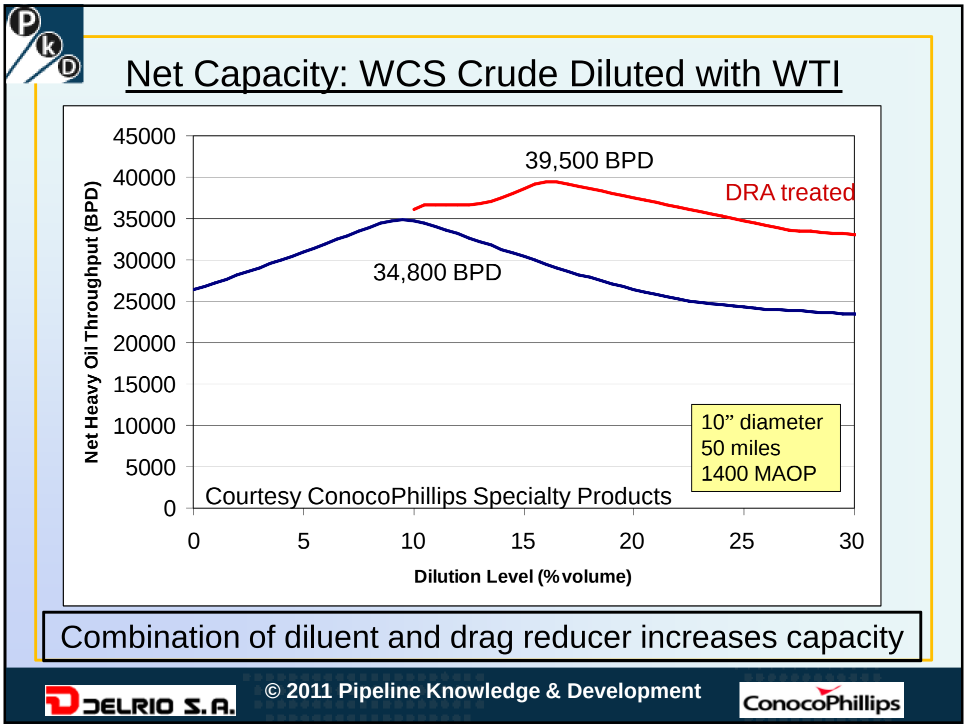

Net Capacity: WCS Crude Diluted with WTI

10” diameter
50 miles
1400 MAOP

Courtesy ConocoPhillips Specialty Products

Combination of diluent and drag reducer increases capacity

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Power Optimization Practices

- Effective scheduling and control
  - Pump and motor operation
    - Avoid unnecessary pump or station operation
    - Select more efficient pumps for a given operating condition
  - Control valve
    - Control valves are energy consuming devices
    - Eliminate excessive suction, flow, or discharge controlling
  - Flow rate – If schedule allows, pump at a lower rate with the minimum number of pumps on-line
  - DRA – Optimize liquid properties; implement pre-determined schedule when the right mix of crude is being transported.
- Equipment
  - Size pumps, motors, valves, and for system operating conditions
  - Consider VFDs as an alternative to control valves
  - Properly maintain equipment
  - Tune pumps to maximize efficiency

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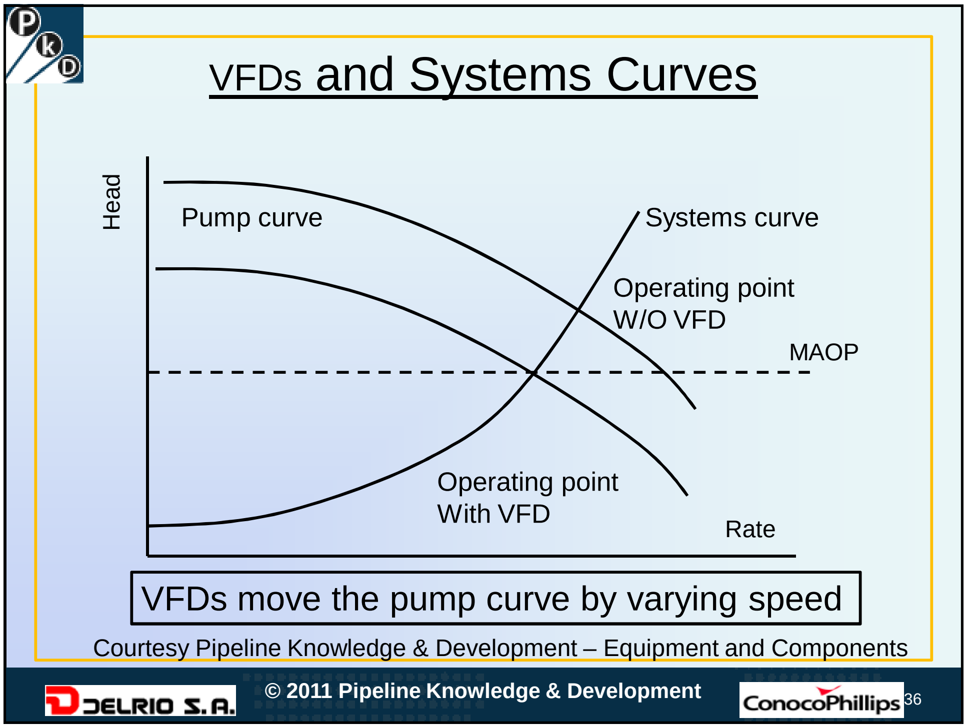

VFDs and Systems Curves

VFDs move the pump curve by varying speed

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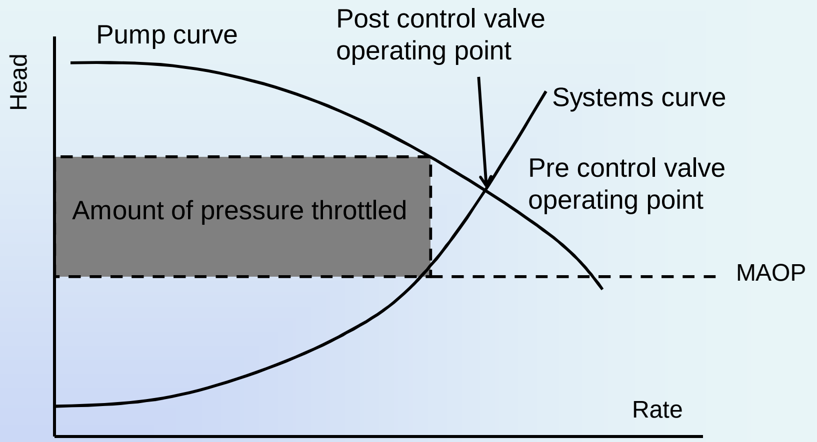
Control Valves and Systems Curves



Pressure is throttled to move the operating point

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Additional Discussion

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