

## Problem 9-7 & 8

**Goal:** Determine optimum Pipe Diameter Effects

**Given:** Turbulent flow

$$\text{Diameters less than 0.0254 m} = 0.49 * (\text{m kg/s} / \text{density kg/m}^3)^{0.49} * (\text{density kg/m}^3)^{0.14} * (\text{viscosity Pa-s})^{0.027}$$

$$\text{Diameters greater than 0.0254 m} = 0.363 * (\text{m kg/s})^{0.45} * (\text{viscosity Pa-s})^{0.025} / (\text{density kg/m}^3)^{0.32}$$

**Assume:** always turbulent flow as stated in problem 9-7

**Approach:** select viscosity, calculate table of  $D_{i\text{opt}}$  for series of flow rates, repeat for each density

plot  $D_{i\text{opt}}$  as function of flow rate for each density

repeat table for different viscosities

## Problem 9-8 Approach:

re-arrange above equations to solve for  $q_r$  in terms of  $D_{i\text{opt}}$

convert m to velocity by dividing by cross sectional area

plot Velocity as function of  $D_{i\text{opt}}$  for each density

$$\text{Diameters less than 0.0254 m} = D_{i\text{opt}} / [ 0.49 * (\text{density kg/m}^3)^{0.14} * (\text{viscosity Pa-s})^{0.027} ]^{(1/0.49)} * (1/\text{PI}()) * (4/ D_{i\text{opt}})^2$$

$$\text{Diameters greater than 0.0254 m} = D_{i\text{opt}} / [ 0.363 * (\text{density kg/m}^3)^{0.13} * (\text{viscosity Pa-s})^{0.027} ]^{(1/0.45)} * (1/\text{PI}()) * (4/ D_{i\text{opt}})^2$$

prepared by: D. C. Drown

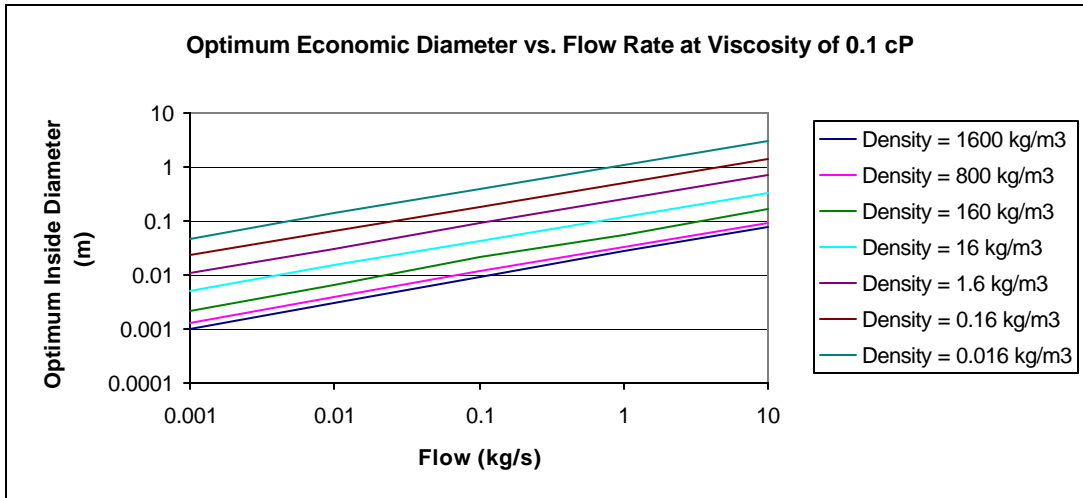
11/28/2004

**Problem 9-7 & 8**

**Goal:** Determine optimum Pipe Diameter Effects

Prob. 9-7 Viscosity = 0.1 cP 0.0001 Pa\*s

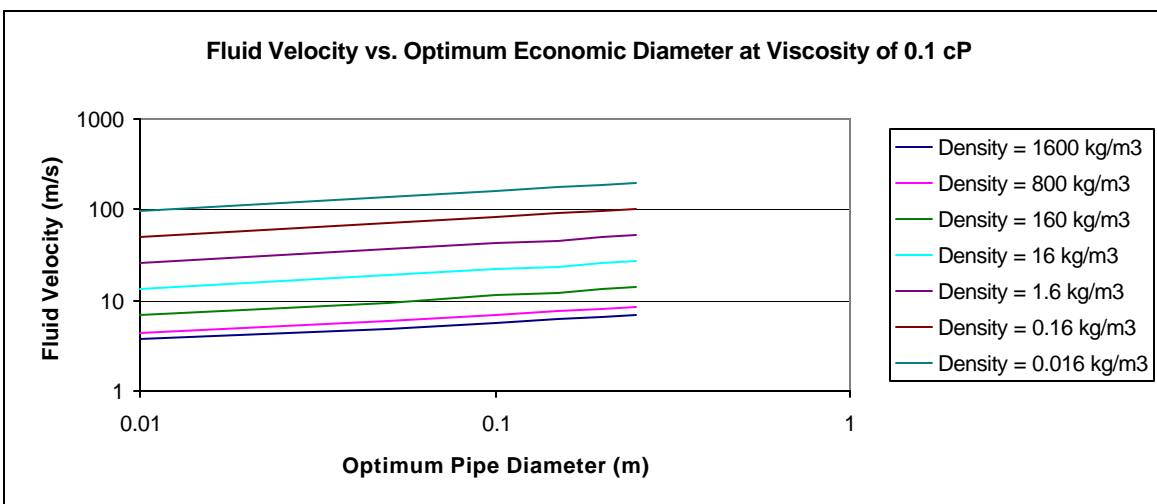
| Density =   | 1600        | 800         | 160         | 16          | 1.6         | 0.16        | 0.016       |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Flow (kg/s) | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ |
| 0.001       | 0.000979    | 0.001248    | 0.002192    | 0.004906    | 0.010984    | 0.023152    | 0.048371    |
| 0.01        | 0.003025    | 0.003856    | 0.006773    | 0.015162    | 0.031231    | 0.065251    | 0.136329    |
| 0.1         | 0.009349    | 0.011916    | 0.020929    | 0.04213     | 0.088021    | 0.183903    | 0.384227    |
| 1           | 0.027201    | 0.033956    | 0.056831    | 0.118738    | 0.248078    | 0.518308    | 1.0829      |
| 10          | 0.076663    | 0.095701    | 0.160173    | 0.334648    | 0.699179    | 1.460791    | 3.052026    |



**Prob. 9-8**

Viscosity = 0.1 cP 0.0001 Pa\*s

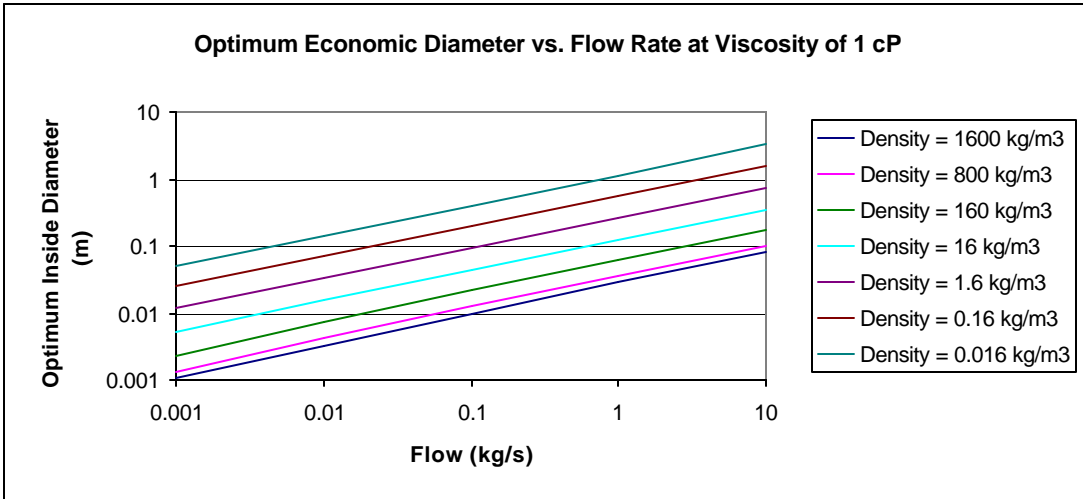
| Density =   | 1600     | 800      | 160      | 16       | 1.6      | 0.16     | 0.016    |
|-------------|----------|----------|----------|----------|----------|----------|----------|
| $D_{i,opt}$ | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity |
| 0.01        | 3.652041 | 4.451888 | 7.050988 | 13.61333 | 26.28322 | 50.74495 | 97.97316 |
| 0.05        | 4.925215 | 6.01713  | 9.578865 | 18.62958 | 36.23196 | 70.46618 | 137.047  |
| 0.1         | 5.745406 | 7.019157 | 11.17402 | 21.73194 | 42.26563 | 82.20084 | 159.8693 |
| 0.15        | 6.287125 | 7.680975 | 12.22759 | 23.78099 | 46.25075 | 89.95135 | 174.943  |
| 0.2         | 6.702183 | 8.18805  | 13.03482 | 25.35094 | 49.30409 | 95.88967 | 186.4922 |
| 0.25        | 7.042905 | 8.60431  | 13.69748 | 26.63972 | 51.81059 | 100.7645 | 195.973  |



**Problem 9-7 & 8**

Prob. 9-7 Viscosity = 1 cP 0.001 Pa\*s

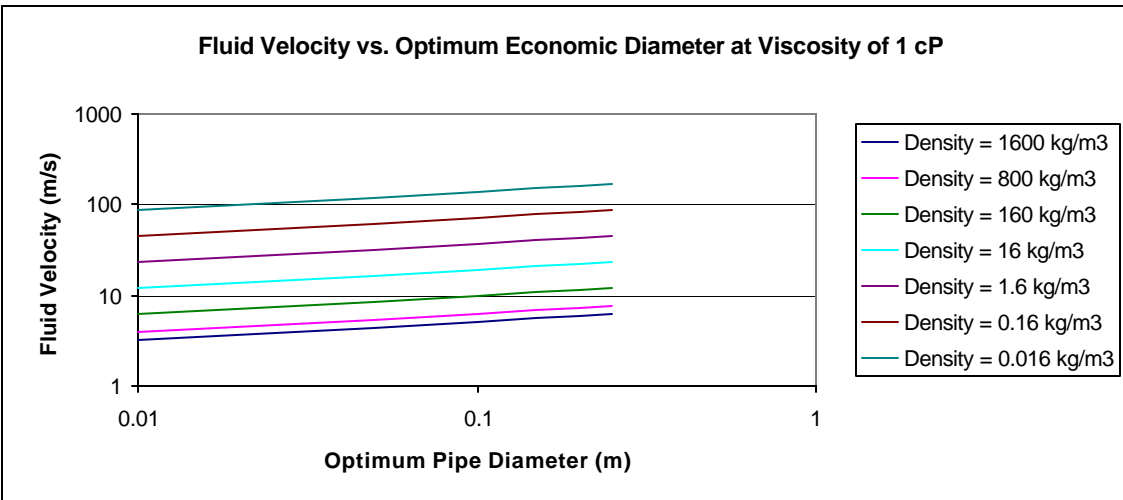
| Density =   | 1600        | 800         | 160         | 16          | 1.6         | 0.16        | 0.016       |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Flow (kg/s) | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ |
| 0.001       | 0.001042    | 0.001328    | 0.002332    | 0.005221    | 0.011688    | 0.024524    | 0.051238    |
| 0.01        | 0.003219    | 0.004103    | 0.007207    | 0.016134    | 0.033082    | 0.069118    | 0.144407    |
| 0.1         | 0.009948    | 0.01268     | 0.022272    | 0.044626    | 0.093237    | 0.1948      | 0.406994    |
| 1           | 0.028813    | 0.035968    | 0.060199    | 0.125773    | 0.262778    | 0.54902     | 1.147066    |
| 10          | 0.081206    | 0.101372    | 0.169663    | 0.354477    | 0.740608    | 1.547349    | 3.23287     |



**Prob. 9-8**

Viscosity = 1 cP 0.001 Pa\*s

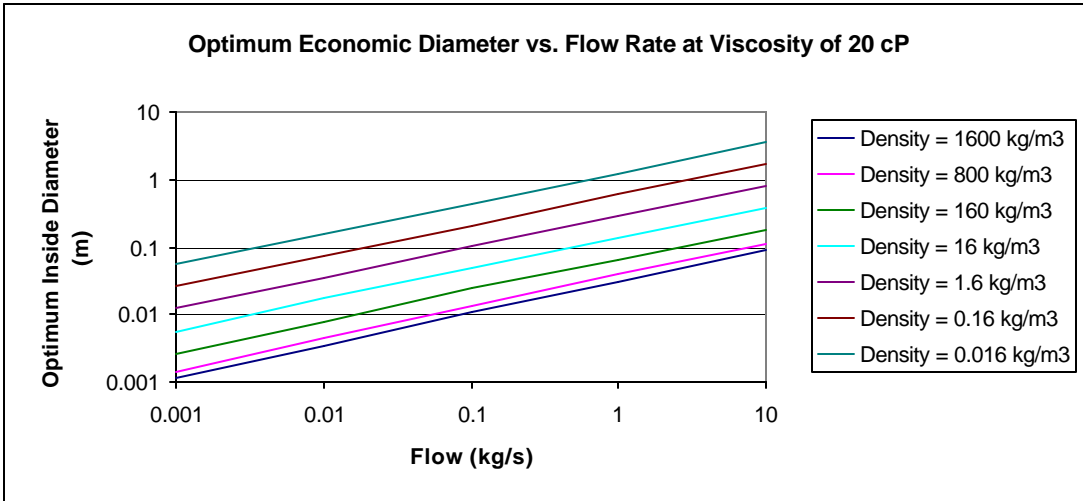
| Density =   | 1600     | 800      | 160      | 16       | 1.6      | 0.16     | 0.016    |
|-------------|----------|----------|----------|----------|----------|----------|----------|
| $D_{i,opt}$ | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity |
| 0.01        | 3.216871 | 3.921409 | 6.210805 | 11.99119 | 23.15136 | 44.69828 | 86.29886 |
| 0.05        | 4.333807 | 5.294608 | 8.428659 | 16.39258 | 31.88132 | 62.00478 | 120.5908 |
| 0.1         | 5.055512 | 6.176314 | 9.832276 | 19.12242 | 37.19048 | 72.33038 | 140.6726 |
| 0.15        | 5.532183 | 6.758663 | 10.75934 | 20.92543 | 40.69708 | 79.15022 | 153.9363 |
| 0.2         | 5.897402 | 7.20485  | 11.46964 | 22.30686 | 43.38378 | 84.37548 | 164.0987 |
| 0.25        | 6.197211 | 7.571127 | 12.05272 | 23.44089 | 45.5893  | 88.66492 | 172.4411 |



**Problem 9-7 & 8**

Prob. 9-7 Viscosity = 20 cP 0.02 Pa\*s

| Density =   | 1600        | 800         | 160         | 16          | 1.6         | 0.16        | 0.016       |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Flow (kg/s) | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ | $D_{i,opt}$ |
| 0.001       | 0.001129    | 0.00144     | 0.002529    | 0.005661    | 0.012673    | 0.026431    | 0.055222    |
| 0.01        | 0.00349     | 0.004449    | 0.007814    | 0.017494    | 0.035654    | 0.074493    | 0.155637    |
| 0.1         | 0.010787    | 0.013748    | 0.024148    | 0.048097    | 0.100488    | 0.209949    | 0.438646    |
| 1           | 0.031054    | 0.038765    | 0.06488     | 0.135555    | 0.283214    | 0.591717    | 1.236272    |
| 10          | 0.087521    | 0.109256    | 0.182858    | 0.382045    | 0.798204    | 1.667685    | 3.484287    |



**Prob. 9-8**

Viscosity = 20 cP 0.02 Pa\*s

| Density =   | 1600     | 800      | 160      | 16       | 1.6      | 0.16     | 0.016    |
|-------------|----------|----------|----------|----------|----------|----------|----------|
| $D_{i,opt}$ | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity | Velocity |
| 0.01        | 2.727371 | 3.324702 | 5.265729 | 10.16653 | 19.6285  | 37.8967  | 73.16707 |
| 0.05        | 3.669359 | 4.482852 | 7.136398 | 13.87931 | 26.99335 | 52.49836 | 102.1021 |
| 0.1         | 4.280414 | 5.229377 | 8.324815 | 16.19062 | 31.48853 | 61.24086 | 119.105  |
| 0.15        | 4.684002 | 5.722441 | 9.109741 | 17.71719 | 34.4575  | 67.0151  | 130.3352 |
| 0.2         | 4.993227 | 6.10022  | 9.711139 | 18.88683 | 36.73229 | 71.43924 | 138.9395 |
| 0.25        | 5.24707  | 6.41034  | 10.20483 | 19.84699 | 38.59966 | 75.07103 | 146.0028 |

