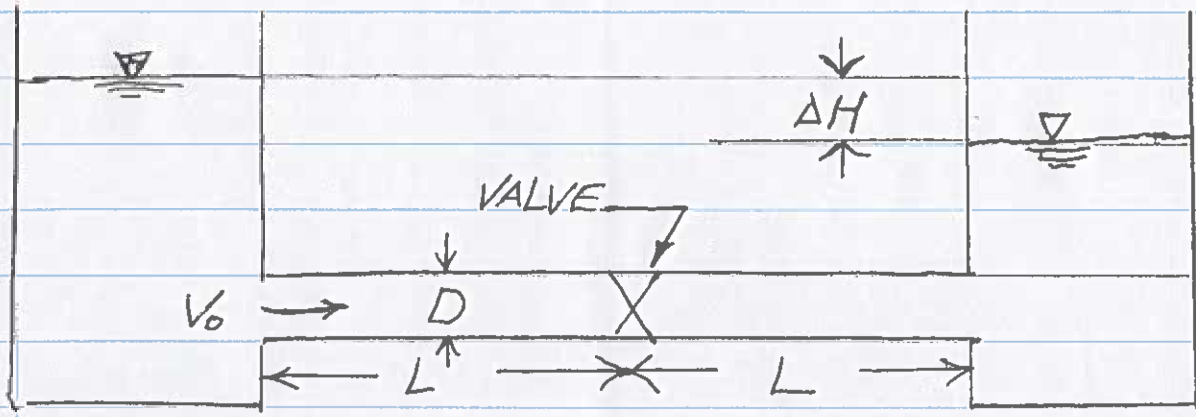
RIGID WATER COLUMN THEORY

VALVE CLOSURE OVER FINITE-TIME; ISOLATING TWO RESERVOIRS



PIPELINE AS SHOWN, VALVE INITIALLY OPEN. VALVE CLOSED IN FINITE TIME SUCH THAT VELOCITY DECREASES LINEARLY TO ZERO IN TIME T_c. ESTIMATE MIN/MAX PRESSURES IN SYSTEM AND TIME OF OCCURANCE

EULER'S EQUATION (FOR EACH SECTION)

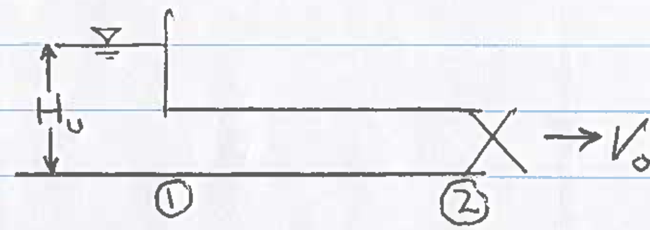
$$\frac{p_2}{\gamma} - \frac{p_1}{\gamma} + \frac{fL}{2g}\frac{V^2}{D} + \frac{L}{g}\frac{dV}{dt} = 0$$

SET VALVE CLOSURE RATE SUCH THAT

$$\frac{dV}{dt} = \frac{-V_0}{T_c}$$

UPSTREAM SECTION

$$\frac{p_2}{\gamma} - \frac{p_1}{\gamma} + \frac{fL}{2gD}V^2 + \frac{L}{g}\frac{dV}{dt} = 0$$



$$\frac{p_2}{\gamma} = H_U - \frac{fL}{2gD}V^2 - \frac{L}{g}\left(-\frac{V_0}{T_c}\right)$$

$$\frac{p_2}{\gamma} = H_U + \frac{V_0 L}{g T_c} - \frac{fLV^2}{2gD}$$

MAX OCCURS WHEN $V \rightarrow 0$, $\frac{p_2}{\gamma} = H_U + \frac{V_0 L}{g T_c}$,
WHICH OCCURS WHEN
THE VALVE IS COMPLETLY CLOSED $(t = T_c)$

MIN OCCURS BEFORE VALVE BEGINS CLOSING
DURING PRE-CLOSURE STEADY FLOW $\left(\frac{dV}{dt} = 0\right)$

$$\frac{p_2}{\gamma} = H_U - \frac{fLV_0^2}{2gD}$$

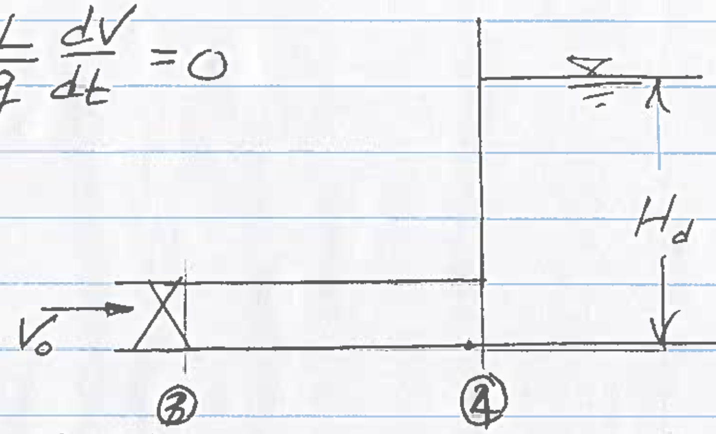
SUMMARY

$$\frac{p_2}{\gamma} = H_U + \frac{V_0 L}{g T_c} \quad @ \; t = T_c$$

$$\frac{p_2}{\gamma} = H_U - \frac{fLV_0^2}{2gD} \quad @ \; t \leq 0$$

DOWNSTREAM SECTION

$$\frac{p_4}{\gamma} - \frac{p_3}{\gamma} + \frac{fL}{2gD}V^2 + \frac{L}{g}\frac{dV}{dt} = 0$$



$$\frac{p_3}{\gamma} = H_d + \frac{fLV^2}{2gD} + \frac{L}{g}\left(\frac{-V_0}{T_c}\right)$$

$$\frac{p_8}{\gamma} = H_d - \frac{L}{g}\left(\frac{V_0}{T_c}\right) + \frac{fLV^2}{2gD}$$

MAX OCCURS WHEN $\frac{dV}{dt} = 0$ (JUST BEFORE VALVE CLOSURE)

$$\frac{p_3}{\gamma} = H_d + \frac{fLV_0^2}{2gD} \quad @ \; t \le 0$$

MIN OCCURS WHEN $V \to 0$ (JUST AT COMPLETE CLOSURE)

$$\frac{p_3}{\gamma} = H_d - \frac{LV_0}{gT_c} \quad @ \; t = T_c$$

R SCRIPT TO EXPLORE SCHEDULED VALVE CLOSURE (AS MANIFEST BY $\frac{dV}{dt}$ = CONSTANT)

INPUTS: $H_U, H_D, L_U, L_D, D, g, f, T_c$

OUTPUTS: $V_0, V(t), \frac{p_2}{\gamma}(t), \frac{p_3}{\gamma}(t)$

ATTACHED CODE & EXAMPLE FOR

$H_U = 100$ ft
$H_d = 80$ ft
$L_U = 3220$ ft.
$L_D = 3220$ ft.
$D =$
$f =$
$T_c = 100$ sec.

NOTES:

```
# Finite-difference approximation for scheduled valve closure
########### Prototype Functions ############
steadyVelocity <- function(head,distance,diameter,gravity,friction){
  steadyVelocity <-
sqrt((2.0*gravity*diameter*head)/(friction*distance))
  return(steadyVelocity)
}
##################################################
# Read Inputs
Hu <- as.numeric(readline(prompt =  "  Enter Upstream Reservoir Pool
Elevation "))
Hd <- as.numeric(readline(prompt =  "Enter Downstream Reservoir Pool
Elevation "))
Lu  <- as.numeric(readline(prompt = "          Enter Upstream Pipeline
Length "))
Ld  <- as.numeric(readline(prompt = "        Enter Downstream Pipeline
Length "))
D  <- as.numeric(readline(prompt =  "                     Enter Pipe
Diameter "))
g  <- as.numeric(readline(prompt =  "             Enter gravitational
constant "))
f  <- as.numeric(readline(prompt =  "              Enter Darcy friction
factor "))
Tc  <- as.numeric(readline(prompt =  "                        Valve
Closure Time "))
# Echo Inputs
message("     Upstream Reservoir Pool Elevation : ",Hu)
message("   Downstream Reservoir Pool Elevation : ",Hd)
message("              Upstream Pipeline Length : ",Lu)
message("            Downstream Pipeline Length : ",Ld)
message("              Pipe Diameter : ",D)
message("     Gravitational Constant : ",g)
message("      Darcy Friction Factor : ",f)
message("         Valve Closure Time : ",Tc)
# Compute Some Constants
DeltaH <- Hu - Hd
TotalL <- Lu + Ld
Vzero <- steadyVelocity(DeltaH,TotalL,D,g,f)
DecelerationRate <- Vzero/Tc
# Report Some Constants
message("                       Vo : ",Vzero)
message(" Deceleration Rate      : ",DecelerationRate)
PmaxUp <- Hu + Lu*DecelerationRate/g
PminUp <- Hu - (f*Lu*Vzero^2)/(2*g*D)
PstartUp <- Hu - (f*Lu*Vzero^2)/(2*g*D) + Lu*DecelerationRate/g
PmaxDn <- Hd + (f*Ld*Vzero^2)/(2*g*D)
PminDn <- Hd - Ld*DecelerationRate/g
PstartDn <- Hd + (f*Ld*Vzero^2)/(2*g*D) - Ld*DecelerationRate/g
message(" Upstream Minimum Pressure Head @ Time < 0 : ",PminUp)
message(" Upstream Pressure Head at Initial Valve Motion @ Time = 0 :",
```

```
PstartUp)
message(" Upstream Maximum Pressure Head @ Time = ",Tc,": ",PmaxUp)
message(" Downstream Maximum Pressure Head @ Time < 0 : ",PmaxDn)
message(" Downstream Pressure Head at Initial Valve Motion @ Time = 0:
", PstartDn)
message(" Downstream Minimum Pressure Head  @ Time = 0 ",Tc,": ",PminDn)
```

RStudio

2ReserviorValveClose.R

```
1 # Finite-difference approximation for scheduled valve closure
2 ########### Prototype Functions ############
3 steadyVelocity <- function(head,distance,diameter,gravity,friction){
4   steadyVelocity <- sqrt((2.0*gravity*diameter*head)/(friction*distance))
5   return(steadyVelocity)
```

Console ~/Dropbox/3-Research/NetworkSimulators/UnsteadyPipeNetwork/RigidWaterColumnTheory/

```
> source('~/Dropbox/3-Research/NetworkSimulators/UnsteadyPipeNetwork/RigidWaterColumnTheory/2ReserviorValveClose.R'
)
 Enter Upstream Reservoir Pool Elevation 100
Enter Downstream Reservoir Pool Elevation 80
          Enter Upstream Pipeline Length 3220
        Enter Downstream Pipeline Length 3220
                     Enter Pipe Diameter 2
            Enter gravitational constant 32.2
             Enter Darcy friction factor 0.004
                      Valve Closure Time 100
    Upstream Reservoir Pool Elevation : 100
  Downstream Reservoir Pool Elevation : 80
             Upstream Pipeline Length : 3220
           Downstream Pipeline Length : 3220
             Pipe Diameter : 2
    Gravitational Constant : 32.2
     Darcy Friction Factor : 0.004
        Valve Closure Time : 100
                     Vo : 10
Deceleration Rate       : 0.1
Upstream Minimum Pressure Head @ Time < 0 : 90
Upstream Pressure Head at Initial Valve Motion @ Time = 0 :100
Upstream Maximum Pressure Head @ Time = 100: 110
Downstream Maximum Pressure Head @ Time < 0 : 90
Downstream Pressure Head at Initial Valve Motion @ Time = 0: 80
Downstream Minimum Pressure Head  @ Time = 0 100: 70
>
```

Files — UnsteadyPipeNetwork > RigidWaterColumnTheory

Name	Size
.RData	24.7 KB
.Rhistory	13.1 KB
2ReserviorValveClose.R	2.3 KB
Example1.jpg	735 KB
Example2.jpg	690.9 KB
ReserviorValveClose.R	2.8 KB
ReservoirValveOpen.R	1.5 KB