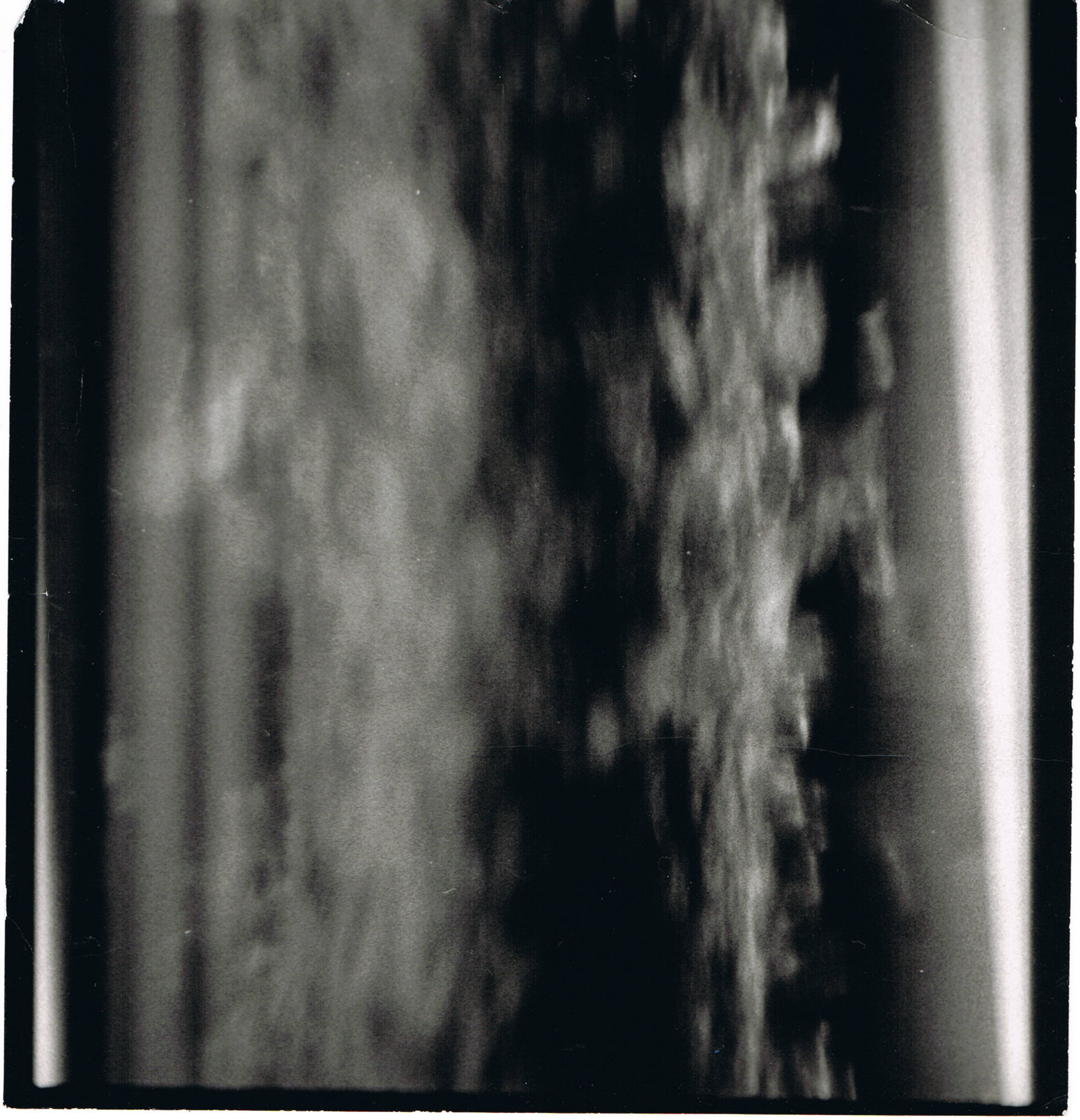

Simulation of Heat Transfer in a Nuclear Reactor.
K. Nour Master's Thesis. University of Illinois
Published
Nuclear Engineering and Design

1980. PP 401-411

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SUBJECT:
RE:

DETAILS CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN ENGINEERING & CONSULTING

CLASS REVIEW SESSON 1:

TERMINAL VELICITY:
MOST EFFICIENT PIPE GEOMETRY:
MOST EFFICIENT OPEN CHANNEL FLOW:
VISCOSITY:
10W30 VS 10W50:
REYNOLDS NUMBER:
LAMINAR
TURBULENT
INERTIA FORCE
VISCOSITY FORCE
CREEPY FLOW
CONSERVATION EQUATIONS
MASS...
ENERGY...MOMENTUM...
ENERGY...
OPEN CHANNEL
CLOSED PIPE FLOW

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DATE: 2/10/15 SHEET: 4
PROJECT: CPD CLASS
SUBJECT: FLOW RATE
RE: Q, V, D, GPM

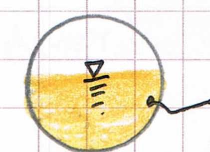
FLOW RATE

Q, FLOW RATE = VA GPM, L/s, Ft³/s

V = VELOCITY, Ft/s, Ft/min

A = SQ INCH, Ft², Ft SQUARE

AREA:



FOR A FULL PIPE FLOW

PIPE DIAMETER, D $\qquad A = \pi \frac{D^2}{4}$

TRY:

D	D^2	π	AREA, in^2	AREA, Ft^2
1"		3.14		
2"		3.14		
3"		3.14		
4"		3.14		

IF VELOCITY IS 2.5 Ft/Sec FOR SEWER PIPE

TRY:

V Ft/s	D	AREA, Ft^2	Q, Ft^3/s	CHALLENGE Q GPM
2.5	1.5"			
2.5	2"			
2.5	3"			
2.5	4"			

FOR HOT WATER MAX. SPEED 5 Ft/s

TRY:

V	D			
5	1"			
5	2"			
5	3"			
5	4"			

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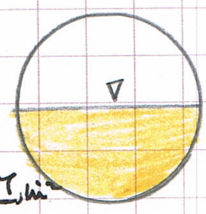
FOR COLD WATER MAX. SPEED = 8 Ft/S

TRY:

V, Ft/S	D	AREA, Ft^2	Q, Ft^3/S	Q, GPM
8	1"			
8	2"			
8	3"			
8	4"			

FOR SEWER 1/2 FULL



$$A_{WET} = \frac{1}{2}\left[\pi \frac{D^2}{4}\right]$$

TRY:

D	D^2	π	A WET, in^2	A WET, Ft^2
1.5"		3.14		
2"		3.14		
3"		3.14		
4"		3.14		

NOW TRY SEWER @ 2 Ft/Sec VELOCITY

D	V Ft/S	A WET, Ft^2	Q, Ft^3/S	Q GPM	~F.U.
1.5"	2				
2"	2				
3"	2				
4"	2				

DISCUSSION:

REVISIONS

DATE: ________ SHEET: ________
PROJECT: ________
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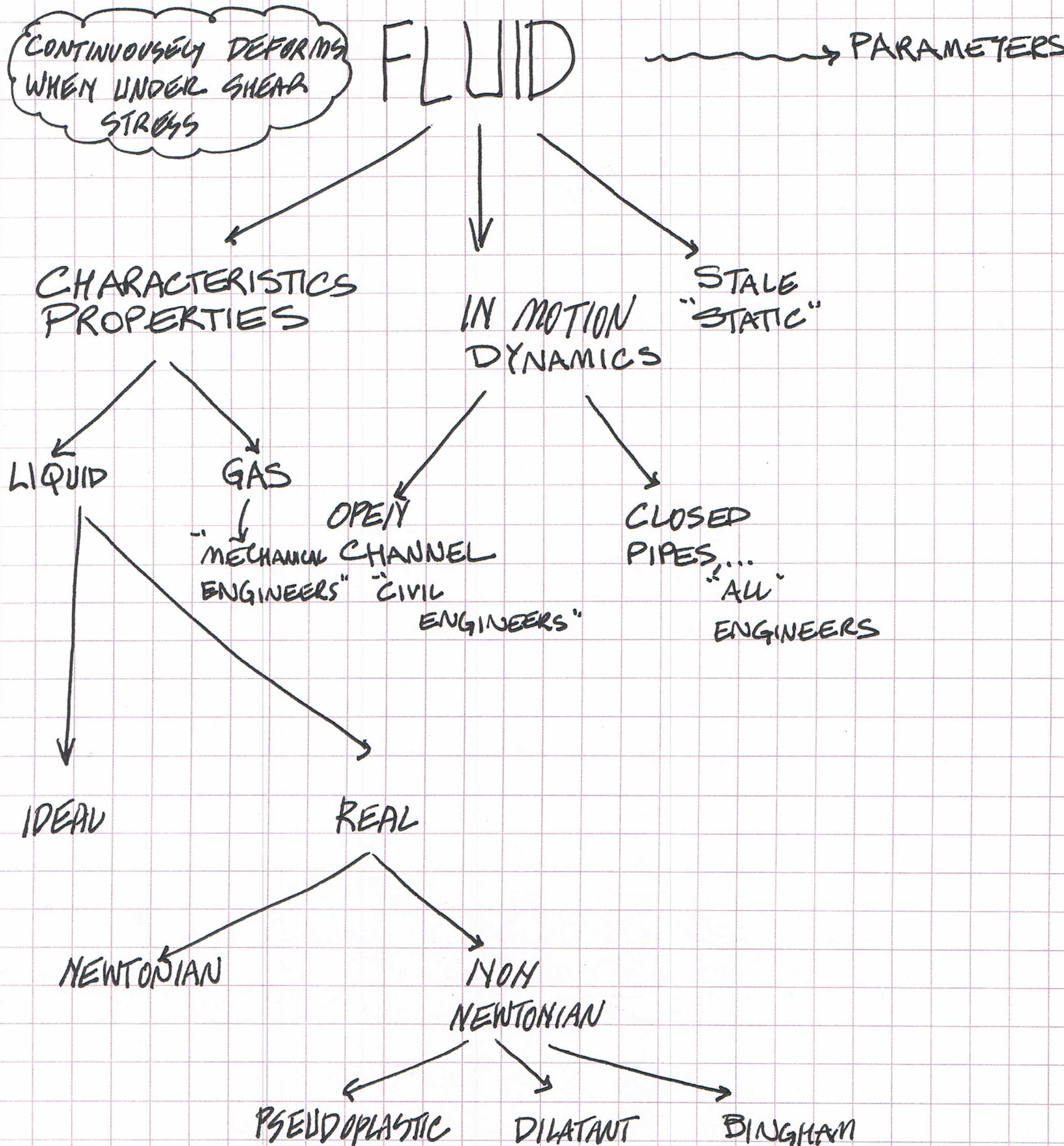
DETAILS   CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN   ENGINEERING & CONSULTING



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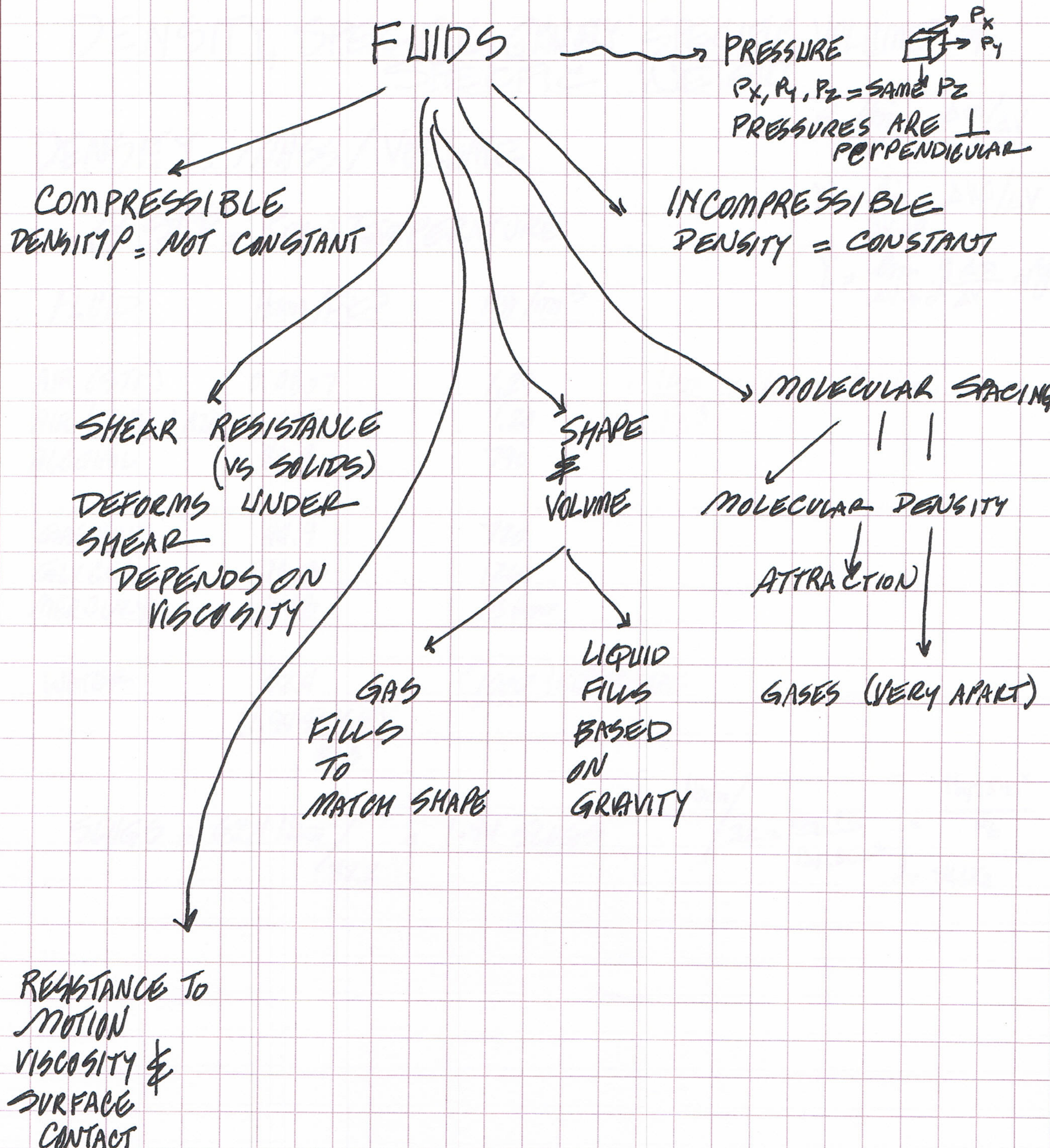


DENSITY, SPECIFIC GRAVITY, SPECIFIC VOLUME & SPECIFIC WEIGHT

DENSITY = MASS / VOLUME

$\rho = \lim_{\Delta V \to 0} \Delta m / \Delta V$

$\gamma = \lim_{\Delta V \to 0} \Delta W / \Delta V$

$\gamma = \lim_{\Delta V \to 0} g \frac{\Delta m}{\Delta V} = \rho g$

@ STP = ROOM TEMPERATURE

FLUID	lbm/Ft³	Kg/m³
AIR (STP)	0.0807	1.29
AIR (70°F, 1 ATM)	0.075	1.20
ALCOHOL	49.3	790
GASOLINE	44.9	720
GLYCERIN	78.6	1260
MERCURY	848	13600
WATER	62.4 (1.94 SLUGS/Ft³)	1000 REFERENCE

$\sim \frac{lbm}{Ft^3} \times 16 = \sim Kg/m^3$

$SLUGS = 62.4\ lbm / 32.2 = 1.94\ SLUGS$ $\left[lbm / 32.2 \frac{lbm \cdot Ft}{lbf \cdot SEC^2} \right] = \frac{lbf \cdot Sec^2}{Ft} = SLUG$

MASS, WEIGHT, GRAVITY ALL RELATED MOON VS EARTH

SPECIFIC ~

SPECIFIC VOLUME: $v = 1/\rho = m^3/Kg$

SPECIFIC GRAVITY: SG_{liq} DENSITY OF FLUID / DENSITY of H_2O

SG_{gas} DENSITY OF GAS / DENSITY of AIR

LIQUID = DENSITY of MATERIAL (OIL, ...) / DENSITY of WATER $1000\ \frac{Kg}{m^3}$

$= (10^{-3}) * {}^{MAT.}Kg/m^3 * m^3/Kg = (0.001)(\rho_{MATERIAL}) =$ UNITLESS

SPECIFIC GRAVITY OF GAS: $\rho_{gas}/\rho_{AIR} = \frac{MW_{GAS}}{MW_{AIR}} = \frac{MW_{GAS}}{29.0} = \frac{R_{AIR}}{R_{GAS}} = \frac{53.3}{R_{GAS}}$

$\rho = P/RT$ $T_1 = T_{AIR}$ $P_1 = P_{AIR}$

$\rho_1/\rho_{AIR} = P_1/R_1T_1 \,/\, P_{AIR}/R_{AIR}T_{AIR} = \frac{R_{AIR}}{R_1}$

STANDARD TEMPERATURE & PRESSURE

SI SYSTEM	273.1 °K	101.325 KPa PRESSURE
SCIENTIFIC	0.0 °C	760 mm Hg
NATURAL gas (CA)	60 °F	
NATURAL gas (US)	60 °F	14.65 Psia, 14.73 or 15.02 Psia
US ENGINEERING	0°C = 32°F	14.696 Psia

SPECIFIC WEIGHT

WEIGHT OF FLUID ((VS) MASS) PER UNIT VOLUME

γ SPECIFIC WEIGHT = (g) MASS / VOLUME

= W / VOLUME

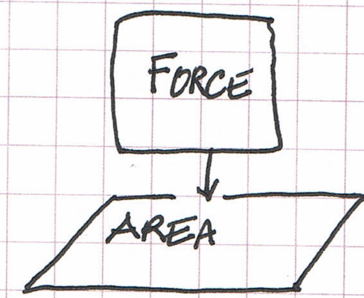
= N/m3 ; lbf/Ft^3

$$\gamma = g\rho = \left(32.2\ \frac{Ft}{Sec^2}\right)\left(1\ lbm/Ft^3\right)(1)$$

$1 \Rightarrow 1\ lbf = 32.2\ lbm\ ft/sec^2 \Rightarrow 1 = 32.2\ \frac{lbm\ Ft}{sec^2\ lbf}$

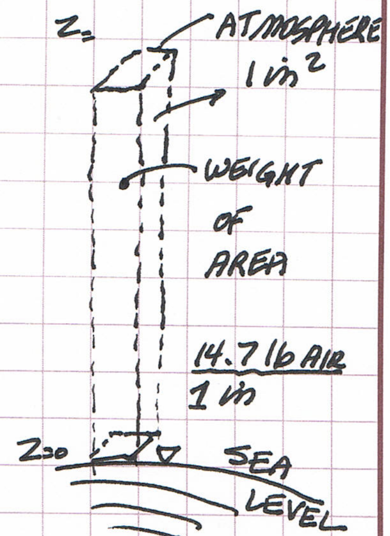
$$= 32.2\ \frac{Ft}{Sec^2} \cdot \frac{lbm}{Ft^3} \Big/ \frac{32.2\ lbm \cdot Ft}{Sec^2 \cdot lbf} = 1\ lbf/Ft^3$$

PRESSURE



FORCE / AREA = PRESSURE

PRESSURE OF AIR @ SEA LEVEL
WEIGHT OF AIR WITHIN 1"x1"x Z = 14.7#
CALLED STP
STANARD TEMPERATURE / PRESSURE
@ SEA LEVEL



STP

14.696 lb PER SQ. INCHE "ABSOLUTE"
1.000 ATMOSPHERE
407.1 in W.g. INCHES OF WATER, INCHE H_2O GAGE
33.93 Ft W.g. FEET OF WATER, FEET WATER GAGE

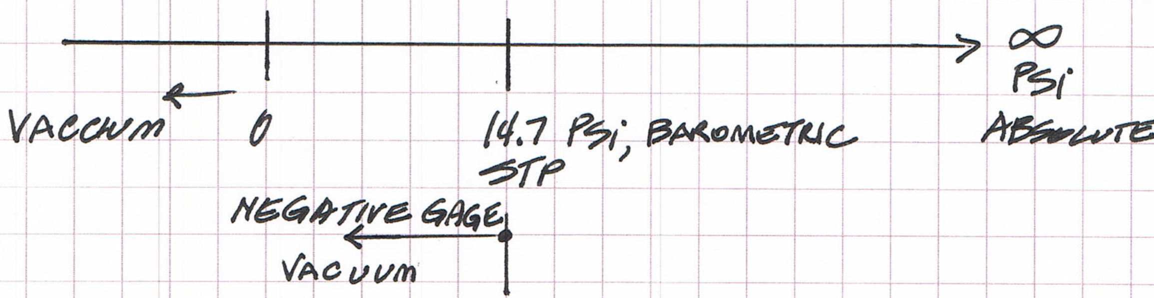
29.921 in Hg INCHES OF MERCURY
760 mm Hg millimeters of mercury
760 TORR

1.013 BARS
1013 MILLIBARS
1.013×10^5 PA PASCAL

101.3 KILOPASCALS

PRESSURE vs VACUUM

UNDER FORCE — UNDER SUCTION



$$P_{ABSOLUTE} = P_{gage} + P_{ATMOSPHERIC}$$

- CONTAINER UNDER VACUUM of 6 PSi
- GAGE PRESSURE MEASURED = 14.7 − 6 = 8.7 PSi gage MEASURED
- PRESSURE GAUGES: READ AMOUNT BEYOND ATMOSPHERIC PRESSURE

  15 PSi MEASURED = 15 PSi + 14.7 PSi = 29.7 PSi <u>ABSOLUTE</u>

- IF ΔP (PRESSURE CONDITION 1 − PRESSURE CONDITION 2) ATMOSPHERIC PRESSURES CANCEL OUT

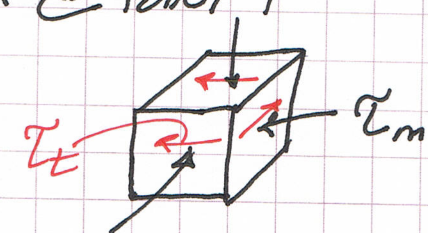
STRESS, τ

$\tau(P)$ = SURFACE STRESS VECTOR @ P_{POINT}

ΔF = FORCE ACTING ON INFITESIMAL AREA ΔA,

ΔA = INFINITESIMAL AREA @ POINT P

$\tau(P) = \lim_{\Delta A \to 0} \Delta F / \Delta A$ @ POINT P



τ_n = NORMAL STRESS @ P

τ_t = TANGENTIAL STRESS

$\tau_n = -p$, PRESSURE @ POINT P

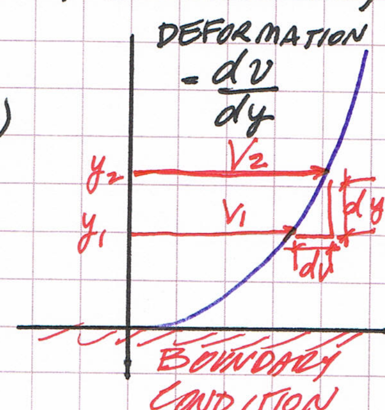
$\tau_t = \mu \, (dv/dy) = \left(\frac{\text{ABSOLUTE DYNAMIC}}{\text{VISCOSITY of FLUID}}\right)\left(\frac{\text{VELOCITY @ B.C.}}{\text{NORMAL DISTANCE}}\right)$

NEWTON'S LAW OF FRICTION OR VISCOSITY

dv = VELOCITY AT BOUNDARY CONDITION (B.C.)

dy = NORMAL DISTANCE, MEASURED FROM BOUNDARY

μ = ABSOLUTE DYNAMIC VISCOSITY
(MEAVRE OF VISCOSITY of FLUID)

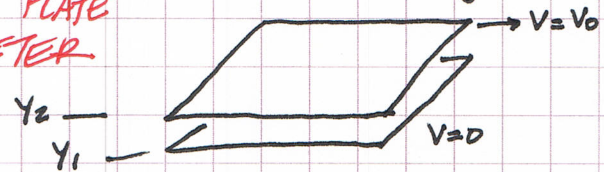


VISCOSITY

NEWTON'S LAW of VISCOSITY

$$\tau = \mu \frac{dv}{dy} = \frac{F}{A}$$

SLIDING PLATE VISCOMETER



$\Delta V = V_0$

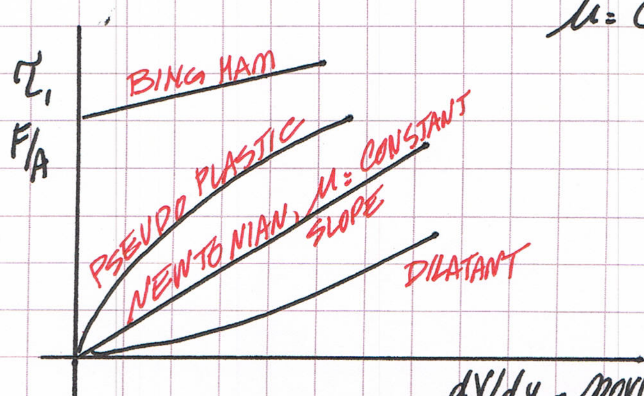
$\Delta y = Y_2 - Y_1$

FORCE REQUIRED HIGHER FOR HONEY THAN WATER

μ: ABSOLUTE "DYNAMIC" VISCOSITY = COEFFICIENT OF VISCOSITY

$\frac{dv}{dy}$: RATE OF STRAIN, SHEAR RATE, VELOCITY GRADIENT, RATE OF SHEAR DEFORMATION

NEWTONIAN FLUID = ν, μ VISCOSITY DOES NOT CHANGE & CHANGE IS LINEAR τ vs $\frac{dv}{dy}$
μ: CONSTANT SLOPE



$dV/dy = \frac{\text{MOVING OF PLATE VELOCITY } V_0}{\text{DISTANCE BETWEEN PLATES } \Delta Y_0}$

PSEUDOPLASTIC : MUDS, MOTOR OILS, POLYMER SOLUTIONS, GUMS, SLURRIES

BINGHAM : BINGHAM PLASTICS: TOOTH PASTE, JELLIES, BREAD DOUGH
INFINITE RESISTANCE TO SMALL SHEAR
MOVE EASILY DURING LARGER STRESS

DILATANT : WITH INCREASING VELOCITY, THE VISCOSITY INCREASES
THIXOTROPIC : VISCOSITY DECREASES WITH TIME
RHEOPECTIC : VISCOSITY INCREASES WITH TIME
TEMPERATURE : DECREASE IN VISCOSITY IN LIQUID & INCREASES μ in GASES

VAPOR PRESSURE

VAPOR PRESSURE OR SATURATION PRESSURE = WHEN MOLECULAR ACTIVITY IN LIQUID PERMITS VAPORIZING OF LIQUID SURFACE

OR VICE VERSA
IT CONDENSES BACK TO LIQUID

VOLATILE LIQUIDS: PROPANE, BUTANE, AMMONIA, FREON
SIGNIFICANT VAPOR PRESSURE @ NORMAL TEMPERATURES
LIQUIDS WHICH ARE NEAR BOILING POINT OR VAPORIZE NEAR NORMAL TEMPERATURES

BOILING: WHEN TEMPERATURE INCREASES TO VAPOR PRESSURE IS EQUAL LOCAL AMBIENT PRESSURE
(a) LOCAL AMBIENT PRESSURE (b) TENDENCY TO VAPORIZE

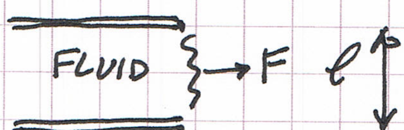
COX CHART: VAPOR PRESSURE NONLINEAR RELATION WITH TEMPERATURE

FLUID	68°F, lbf/ft²	20°C KPA
· MERCURY	0.00362	0.000173
· TURPENTINE	1.115	0.0534
· WATER	48.9	2.34
· ETHYL ALCOHOL	122.4	5.86
· ETHER	1231	58.6
· BUTANE	4550	218
· FREON 12	12,200	584
· PROPANE	17,900	855
· AMMONIA	18,550	888

SURFACE TENSION, σ

σ, SURFACE TENSION: FORCE ACTING ON MEMBRANE (SKIN) OF FLUID DUE TO COHESIVE MOLECULAR FORCES.

EFFECTS: NEEDLES CAN FLOAT
INSECTS TO SIT ON FLUID
DROPLETS ARE SPHERICAL (LEAST SURFACE AREA IN ANY VOLUME)



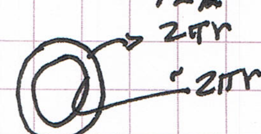
STRETCH FILM OF LIQUID

2 SURFACES, ONE CONSTANT FORCE, DISTANCE ℓ

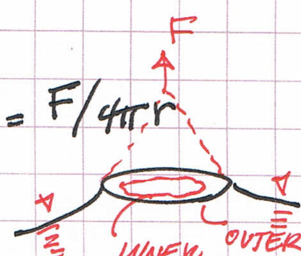
UNITS: N/m; DYNES/cm; lbf/ft; lbf-ft/ft²

$\sigma = F/2\ell$

RING:



$\sigma = F/2(2\pi r) = F/4\pi r$



σ: DECREASE WITH TEMPERATURE

: GAS IN CONTACT WITH LIQUID INCREASE CHANGES σ

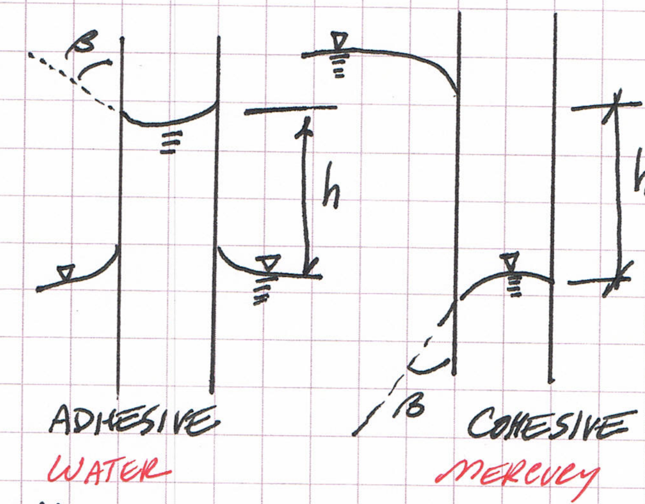
σ: CAUSES PRESSURE INSIDE & OUTSIDE of BUBBLE or DROPLETS BE DIFFERENT

$$\sigma_{BUBBLE} = \frac{r(P_{INSIDE} - P_{OUTSIDE})}{4}$$

$$\sigma_{DROPLE} = \frac{r(P_{INSIDE} - P_{OUTSIDE})}{2} \; ?$$

CAPILLARY ACTION = SURFACE TENSION OF LIQUID & SOLID SURFACE

- BEHVIOR OF LIQUID IN THIN-BOR TUBE
- ADHESION WITH SURFACE > COHESION OF MOLECULES
- CURVED SURFACE = MENICUS
- IF DIAMETER ~< 0.1 inch



$r_{menicus} = r_{TUBE}$

- IN MERCURY = COHESIVE MOLECULAR FORCE > ADHESIVE
- $\beta > 90°$ = COHESIVE FORCE DOMINATES
  $\beta < 90°$ = ADHESIVE FORCES DOMINATE

β angle of CONTACT

MERCURY GLASS	140°
WATER - PARAFFIN	107°
WATER - SILVER	90°
KEI	
KEROSENE - GLASS	26°
GLYCERIN - GLASS	19°
WATER - GLASS	0°
ETHYL ALCOHOL, GLASS	0°

$$h = \frac{4\sigma\cos\beta}{\rho\, d_{tube}\, g} = \frac{4\sigma\cos\beta}{\rho d_{tube}}\left(\frac{g_c}{g}\right) = \frac{4\sigma\cos\beta}{\rho\, d_{tube}\, g}$$

$$\sigma = \frac{h\rho\, d_{tube}\, g}{4\cos\beta} = h\rho\, d_{tube}\, g/4\cos\beta$$

$$= \frac{h\rho\, d_{tube}}{4\cos\beta}\ g/g_c$$

$r_{menicus} = r_{tube}$; $\beta = 0°$, $\cos\beta = 1.0$

if capillary < 0.1 in $\beta = 0°$

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KINEMATIC VISCOSITY $\nu = \frac{\mu}{\rho}$

ν = KINEMATIC VISCOSITY = ABSOLUTE VISCOSITY / MASS DENSITY

$= \frac{\mu}{\rho} = \mu g_c / \rho$

UNITS

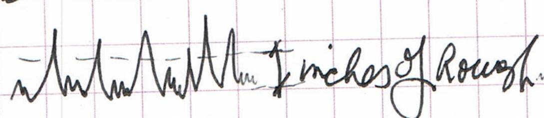
μ (ABSOLUTE)	ν (KINEMATIC)	
lbf-SEC / Ft^2 SLUG / Ft.SEC	Ft^2 / SEC	BRITISH
DYNES.S / cm^2 (POISE)	cm^2/sec (STOKE)	METRIC
Pa.S N.S/m^2	m^2/sec	SI

ε. ROUGHNESS

SURFACE ROUGHNESS DEPENDS ON MATERIAL, AGE of MATERIAL, ELEMENTS ATTACHED TO SURFACE, (ALGAE, OXIDATION, ...)

THERE ARE GENERAL PARAMETERS USED:

a. ACTUAL ROUGHNESS, e, OR ε



$e_{GLASS} < e_{CAST\ IRON}$

b. MANNING COEFFICIENT OF ROUGHNESS (NO UNITS), n

CAST IRON $n = 0.012$ $D = 1\frac{1}{2}"$
$= 0.013$ $D = 2", 3"$
$= 0.014$ $D = 4"$
$= 0.015$ $D = 5", 6"$
$= 0.016$ $D > 8"$

STORM DRAIN:
$n = 0.015$
ALL PIPES

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DATE: 2/10/15 SHEET: 3
PROJECT: CPD CLASS
SUBJECT: HYDRAULIC RADIUS
RE: GEOMETRIES V ⌴ ◒

DETAILS CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN ENGINEERING & CONSULTING

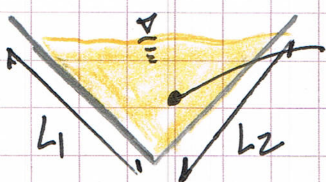
HYDRAULIC RADIUS

SINCE ALL EQUATIONS ARE FOR PIPES: (FULL FLOW) ALL GEOMETRIES HAVE TO BE CONVERTED INTO CIRCLE THEREFORE WE USE HYDRAULIC RADIUS TO PRETEND "CIRCLE".

R_h = HYDRAULIC RADIUS =

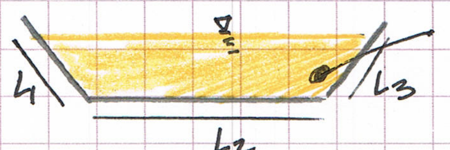
$$\frac{\text{WETTED AREA OF FLOW}}{\text{WETTED PERIMETER OF FLOW}}$$

a. TRIANGLE



$$\frac{\text{AREA OF WATER}}{\text{PERIMETER WETTED}, L_1+L_2}$$

b. TRAPEZOID



$$\frac{\text{AREA OF WATER}}{\text{PERIMETER WETTED}, L_1+L_2+L_3}$$

c. HALF CIRCLE

$$\frac{\text{AREA OF WATER}}{\text{WETTED PERIMETER}} = \frac{(\pi D^2/(2)(4))}{(\pi D)/2}$$

$$R_h = \frac{\frac{1}{2}(\pi D^2)/4}{\pi D/2} = \frac{1/8}{1/2}\,\frac{\pi}{\pi}\,\frac{D^2}{D} = \frac{1}{4}D = \frac{\text{RADIUS}}{2}\ \text{PIPE}$$

TRY D	½ FULL R_h, INCHES
1.5"	
2"	
3"	
4"	

R_h (HYDRAULIC RADIUS) = ½ (PIPE RADIUS) @ ½ FULL

DISCUSSION

HYDRAULIC SLOPE, S

Ft/Ft

HYDRAULIC SLOPE IS CAUSATION FOR ENERGY IN FLUID TO MOVE

THE RISE WITHIN RUN OF A PIPE GIVE "POTENTIAL HEAD" "ENERGY HEAD"

RIVERS MOVE BASED ON SLOPE, OTHERWISE IT IS "LAKE"

$S = \frac{RISE}{RUN} = \frac{1/2"}{1 Ft} = \left(\frac{1}{2}"\right) / 12" = \frac{1"}{24"}$ = 0.0416, 4.16% ~4%

$= \frac{1/4"}{Ft} = \frac{1}{4"} / 12" = \frac{1"}{48"}$ = 0.0208, 2.08% ~2%

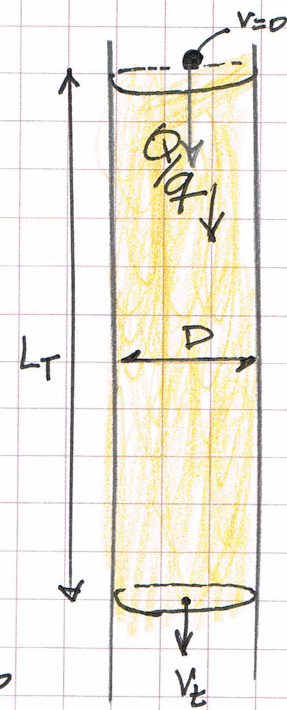
$= \frac{1/8"}{Ft} = \frac{1}{8"} / 12" = \frac{1}{96"}$ = 0.0104, 1.04%, ~1%

TRY: (CIVIL) $= \frac{1/16"}{Ft} =$ / = ___

(NO BODY) $= \frac{1"}{Ft} =$ / = ___

(CIVIL) $= \frac{1/32"}{Ft} =$ / = ___

TERMINAL VELOCITY & LENGTH



WHEN AN OBJECT (WATER) FALLS THROUGH PIPE, THE VELOCITY STARTS AT ZERO VELOCITY (INITIAL) TO A MAXIMUM VELOCITY CALLED

"TERMINAL VELOCITY" V_T

IT STAYS AT THIS SPEED TILL IT REACHES DESTINY.

DISTANCE TILL REACHING V_T IS CALLED "TERMINAL LENGTH"

$$V_T = 3.0 \left(Q_{GPM} / D_{INCHES} \right)^{2/5} = 3\left(\frac{Q}{D}\right)^{0.4} \text{, Ft/sec}$$

IN CALCULATOR (MOST) → V_T = 3*(Q÷D)^0.4

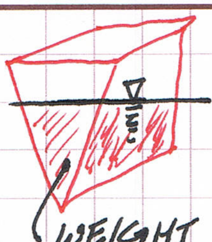
$$L_T = 0.052 (V_T)^2 \text{, Ft}$$

(10 Ft)
(15 Ft)

= 0.052*(V_T)*(V_T)
= 0.052*(VT)^2

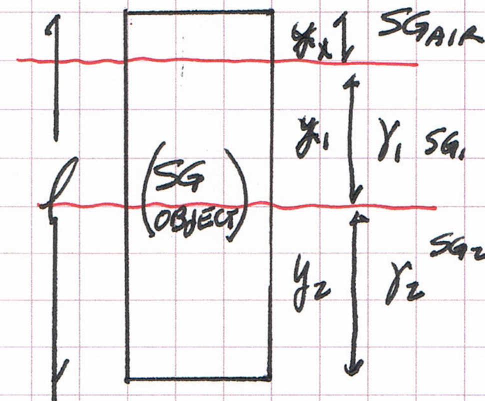
TRY	Q GPM	D INCHES	VT Ft/s	LT Ft
	5	2		
	10	2		
	15	2		
	5	4		
	10	4		
	15	4		

DISCUSSION:



BOUYANCY

$F_B = \gamma$ VOLUME DISPLACED



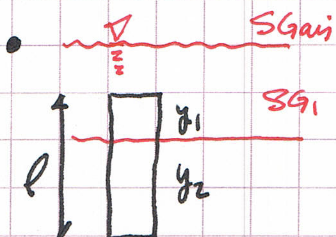
WEIGHT EQUIVALENT OF VOLUME OF WATER DISPLACED = F BOUYANCY UPWARD

$$(SG)_{OBJECT} = \frac{W_{DRY}}{W_{DRY} - W_{SUBMERGED}}$$

$$SG\Big|_{OBJECT} = y_1(SG_1) + y_2(SG_2)$$

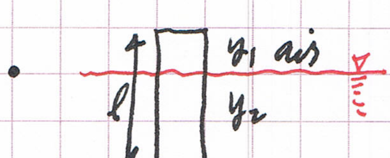
SG air ≅ φ

$$= (\ell - y_x - y_2)(SG_1) + y_2(SG_2) = y_1 SG_1 + (\ell - y_x - y_1)(SG_2)$$

- 

$\ell = y_1 + y_2$

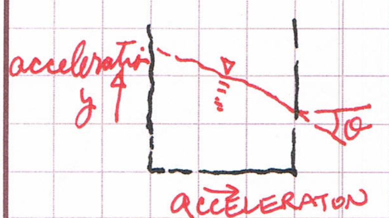
$$y_1 = \frac{SG_2 - SG_{OBJECT}}{SG_2 - SG_1} \; ; \; y_2 = \ell - y_1$$

- 

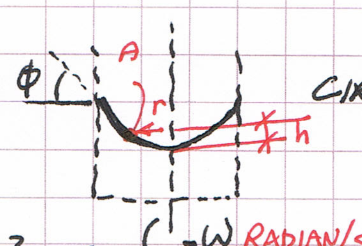
$$y_2 = \frac{SG_{OBJECT}}{SG_2}$$

$y_1 = \ell - y_1$

MOTION:



TRANSLATION



CIRCULAR

$$p = \gamma h(1 + a_y/g)$$

$$\phi = \arctan\left(a_x / (a_y + g)\right)$$

$$h = \frac{(\omega r)^2}{2g} = \frac{V^2}{2g}$$

$$\phi = \arctan\left(\frac{\omega^2 r}{g}\right)$$

COMPRESSIBILITY (β, COEFFICIENT of COMPRESSIBILITY)

$\beta = \frac{\text{FRACTIONAL CHANGE IN VOLUME}}{\text{CHANGE IN PRESSURE}}$ @ CONTANT TEMPREATURE

$= (-\Delta V / V_0) / \Delta P = 1/E = 1/\text{BULK MODULUS}$

$= \frac{-1}{V_0}\left(\frac{\partial V}{\partial P}\right)_T = \frac{-1}{\rho_0}\left(\frac{\partial \rho}{\partial P}\right)_T$ INSIGNIFICANT CHANGE WITH TEMPERATURE = INCOMPRESSIBLE

DENSITY @ PRESSURE "2" $= \rho_2 \approx \rho_1 \left[1 + \beta (P_2 - P_1)\right]$

THERMAL COEFFICIENT of EXPANSION $= 1/V_0 \left(\partial V / \partial T\right)_P$ $1/°F$, $1/°C$

$= Z$ COMPRESSIBILITY FACTOR

GASES: EASILY COMPRESSED

$\beta_T = 1/P$ (ISOTHERMAL IDEAL GAS PRESSURE)

$\beta_S = \frac{1}{kP}$ (ADIABATIC IDEAL GAS PROCESS)

BULK MODULUS, E ~MODULUS OF ELASTICITY

SECANT BULK MODULUS

$$E = \frac{\text{STRESS}}{\text{STRAIN}} = \frac{-\Delta P}{\Delta V / V_0} = \frac{\text{INCREASE IN STRESS}}{\text{VOLUMETRIC STRAIN}}$$

~ SIMILIAR TO HOOKS LAW

$$= -V_0 \left(\frac{dP}{dV}\right)_T$$ ORIGINAL VOLUME (RATE PRESSURE TO VOLUME) CONSTANT TEMP.

[TANGENT BULK MODULUS & POINT BULK MODULUS]

E = BULK MODULUS = 1/(COMPRESSIBILITY, β) ~TEMPERATURE CHANGE IS MINOR

BULK MODULUS OF WATER, 1000 Psi

PRESSURE, Psi	32°F	68°F	120°F	200°F	300°F
15	292	320	332	308	
1500	300	330	340	319	218
4500	317	348	362	338	271
15,000	380	410	420	405	350

↳ = 320 000 + 6P ↗P (PRESSURE IN GAGE, Psi)

SPEED OF SOUND

REMEMBER 4th of JULY LIGHT & SOUNDS OF EVENTS

a: SPEED OF SOUND
ACOUSTICAL VELOCITY
SONIC VELOCITY

$$a = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{1}{\beta\rho}} = \sqrt{\frac{E g_c}{\rho}} = \sqrt{\frac{g_c}{\beta\rho}}$$

E = BULK MODULUS OF SOLIDS

β = COMPRESSIBILITY

k = CONSTANT IDEAL GAS
R = CONSTANT IDEAL GAS

$$a = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{kP}{\rho}} = \sqrt{kRT} = \sqrt{\frac{kR^*T}{MW}} = \sqrt{\frac{E g_c}{\rho}} = \sqrt{\frac{k g_c P}{\rho}} = \sqrt{k g_c R T} = \sqrt{\frac{k g_c R^* T}{MW}}$$

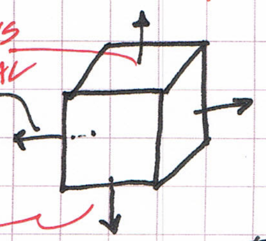
$$\frac{a_1}{a_2} = \sqrt{\frac{T_1}{T_2}}$$ NEW SPEED @ DIFFERET TEMPERATURE

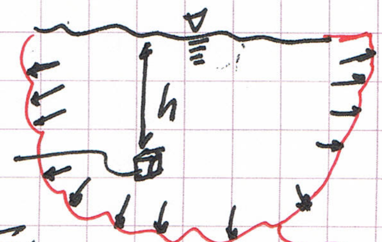
M = MACK NUMBER = SPEED OF OBJECT IN A MED / SPEED OF SOUND IN MEDIUM
$= V/a$

SUB SONIC	$M < 1$
SUPER SONIC	$5 > M > 1$
HYPER SONIC	$M > 5$
TRANSONIC	$1.2 > M > 0.8$
SONIC BOOM	WHEN (SHOCK WAVE) SUBSONIC TO SUPERSONIC

HYDROSTATIC PRESSURE

PASCAL'S LAW
PRESSURE EXERTED OUT ON ALL SIDES
ALWAYS NORMAL
FLUIDS: NO SHEAR





BOWL

PRESSURE ON SIDES OF BOWL $P = F/A$
FORCE EXERTED per square UNIT ~~of~~ AREA

$P \propto h$ ∴ PRESSURE @ h is SAME REGARDLESS OF SHAPE of BOWL

$P = \rho g h = \frac{\rho g h}{g_c} = \gamma h$

$h = \frac{P}{\gamma}$

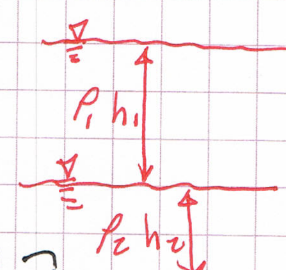
R_F : RESULTANT FORCE ALWAYS @ CENTER OF PRESSURE

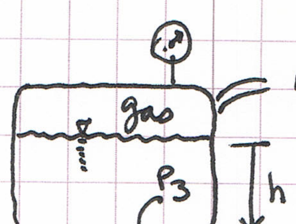
H_2O: @ 68°F = 0.036 Psi/in = 62.4 PSF/ft = 9.8 KPa/m = 2.31 ft/Psi, water
Hg : @ 68°F = 0.491 Psi/in = 133.4 KPa/m mercury

IF VAPOR PRESSURE IS CRITICAL, VAPOR PRESSURE REDUCES EFFECTIVE HEIGH IN BAROMETER

$P_a - P_v = \rho g h = \frac{\rho g h}{g_c} = \gamma h$ P_v @ 68°F, 20°C = 0.34 Psi (2.34 KPa)

- MULTI FLUIDS
$P_3 = \rho_1 g h_1 + \rho_2 g h_2 = \gamma_1 h_1 + \gamma_2 h_2$

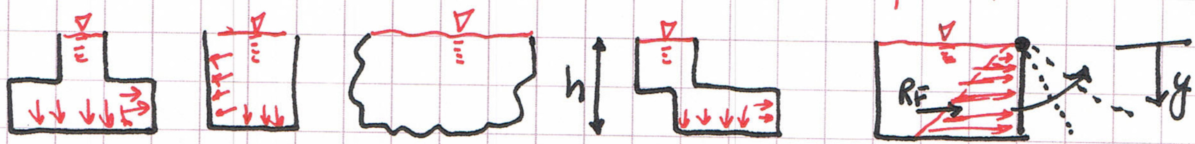


- 

PEXTERNAL

$P_3 = P_{EXTERNAL} + \gamma h$
PRESSURIZED TANK

PRESSURES ON HORIZONTAL & VERTICAL PLATES



HORIZONTAL FORCES: VARY FROM TOP LINEARLY INCREASING AS DISTANCE y INCREASES
TRIANGULAR SHAPE WITH CENTER OF FORCE BEING THE CENTER OF GEOMETRIC SHAPE of FORCE DISTRIBUTION

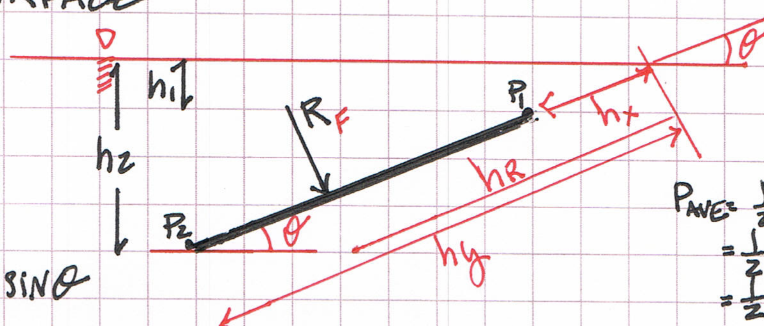
VERTICAL FORCE: ALWAYS SAME @ $p = \gamma h$
$F = pA$ BASE AREA
ONLY h is PARAMETER REGARDLESS of SHAPE

INCLINED SURFACE

$R_F = P_{AVE} A$

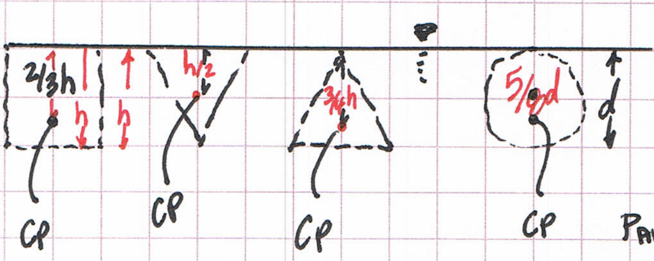
$P_{AVE} = \frac{1}{2}\gamma(h_1 + h_2)$

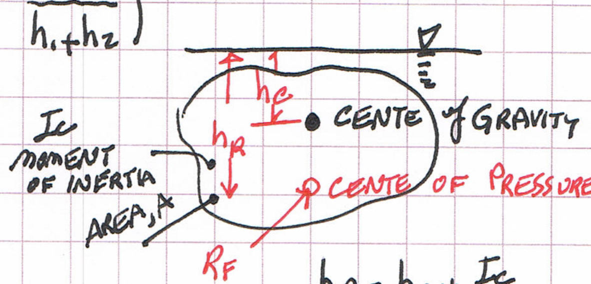
$= \frac{1}{2}\gamma(h_x + h_y)\sin\theta$



$P_{AVE} = \frac{1}{2}(P_1 + P_2)$
$= \frac{1}{2}\gamma(h_1 + h_2)$
$= \frac{1}{2}\gamma(h_x + h_y)\sin\theta$

$$h_R = \frac{2}{3}\left(h_x + h_y - \frac{h_x h_y}{h_x + h_y}\right) = \frac{2/3}{\sin\theta}\left(h_1 + h_2 - \frac{h_1 h_2}{h_1 + h_2}\right)$$





$P_{AVE} = \gamma h_c \sin\theta$
$R_F = P_{AVE} A$

$h_R = h_c + \frac{I_c}{A h_c}$

CURVED & COMPOUND SURFACES

$R = [R_x^2 + R_y^2]^{1/2}$

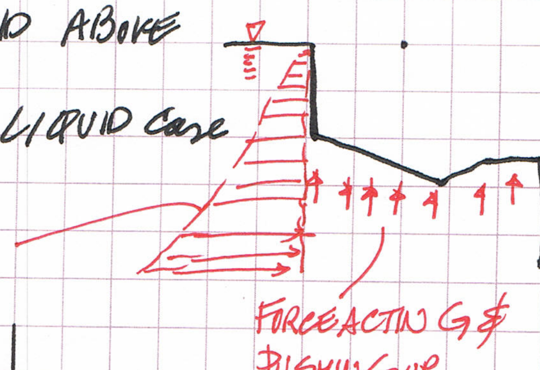
$\theta = \arctan(R_y/R_x)$

R_x HORIZONTAL FORCE SEES THE PROJECTION OF SHAPE IN X DIRECTION, THEREFOR VERTICAL PLANE

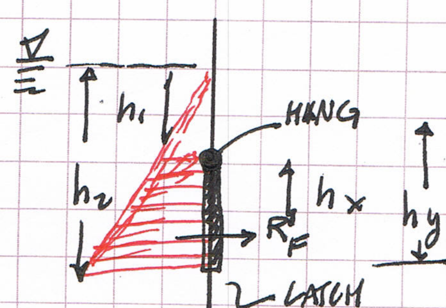
R_y = WEIGH EQUIVALENT ON TOP OF THE PROJECTED HORIZONTAL SURFACE AREA

FIND WEIGHT OF LIQUID ABOVE

IF IT WAS A BOAT OR MISSING LIQUID Case



FORCE ON GATE:



LATCH FORCE * hy = R_F hx = }

L_F (LATCH FORCE) = $\frac{R_F h_x}{h_y}$

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REVISIONS

SHEET NUMBER 1/
JOB NAME: HYDRAULICS
RE: PRESSURE
DATE 3/30/05

DETAILS

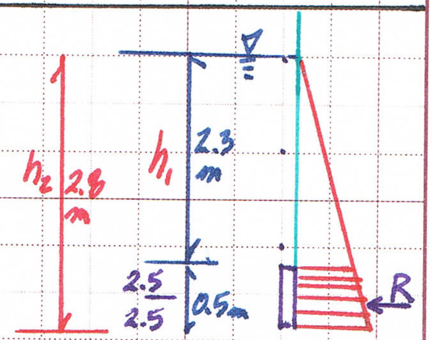
ENGINEERING & CONSULTING

GATE HINGED @ TOP TO PREVENT BACKFLOW OF TIDAL WATER INTO a 0.5m CIRCULAR STORM WATER. AT HIGH TIDE GATE (TOP) IS 2.3m BELOW WATER. WHAT FORCE IS REQUIRED TO OPEN GATE @ HIGH TIDE?

R = FORCE ON GATE IS CALCULATED @ CENTER OF GATE = $\frac{h_1+h_2}{2} = \frac{2.3+2.8}{2}$

$$R = A\Big|_{\substack{GATE\\AREA}} \underbrace{\rho g}_{\gamma} \left(\frac{h_1+h_2}{2}\right) = \underbrace{\frac{\pi(0.5)^2}{4}}_{0.2m^2} \gamma \underbrace{\left(\frac{2.3+2.8}{2}\right)}_{2.55}$$

$$= 0.2m^2 \left(1000\frac{kg}{m^3} \cdot 9.81\frac{m}{s^2}\right) 2.55 = \underline{5003\,N}$$

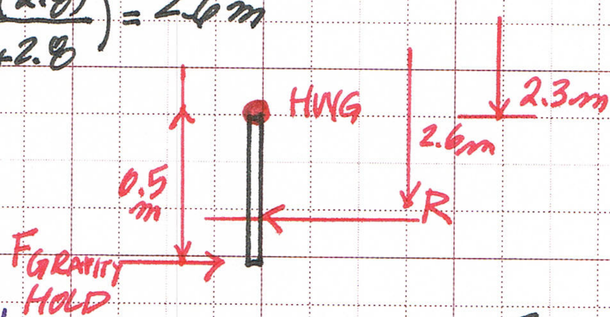


FORCE IS APPLIED @ 2/3 OF $\frac{2}{3}\left(h_1+h_2 - \frac{h_1 h_2}{h_1+h_2}\right) = d_R$

$$d_R = \frac{2}{3}\left(2.3 + 2.8 - \frac{2.3(2.8)}{2.3+2.8}\right) = 2.6m$$

$$\sum M_{HING} = \phi$$

$$F_G(0.5) = R(2.6-2.3)$$
$$= 5003(0.3)$$



$$F_G = 3.0\,KN = 3000\,N$$

$\underline{\underline{3000\,N}}$

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REVISIONS

DATE: SHEET:
PROJECT:
SUBJECT:
RE:

PIPE MATERIALS

SMOOTHNESS ←
CORROSION ←
COST ←

→ WATER DISTRIBUTION
→ WASTE WATER
→ AIR CONDITIONING (REF.)
→ PRESSURE
→ EXTERNAL LOAD

MATERIAL	DESCRIPTION
• DUCTILE CAST IRON	STRONG, COSTLY, HEAVY, IMPERVIOUS, SCOUR RESISTANCE
• GRAY CAST IRON	SAME AS DUCTILE CAST IRON
• ASBESTOS CEMENT	LIGHT WEIGHT, CORROSION RESISTANCE, NO ELECTROLYSIS, WEAK STRUCTURALLY
• CONCRETE	WATER TIGHT, DURABLE, SMOOTH INTERIOR, LOW MAINTENANCE
• VITRIFIED CLAY	CORROSION RESISTANCE, SCOUR, EROSION, RESISTANCE
• STEEL	DUCTILE, HIGH STRENGTH, SMOOTH INTERIOR, SUBJECT TO CORROSION, RESISTANCE TO SHOCK
• PLASTIC	PVC & ABS; CHEMICALLY INERT, CORROSION RESTANCE LOW COST
• COPPER & BRASS	WATER, CONDENSATE, ...

HYDRAULIC SHOCK

A SUDDEN SURGE IN VELOCITY of FLUID (ERRONEOUSLY KNOWN AS WATER HAMMER).

SUDDEN INERTIA (NEAR ≈ 3000 mi/hr POSSIBLE) IN PIPE CAUSES MAJOR IMPULSE FORCE ON SIDES & BENDS THE DYNAMIC PRESSURE WAVE WITHIN PIPE HAS MAJOR STRUCTURAL IMPLICATION ON PIPE JOISTS, PIPE MATERIAL, & PIPE SUPPORTS.

NOISE IS SECONDARY CAUSES NUISANCE FOR BUILDING OCCUPANTS. VIBRATING PIPES CAUSES FATIGUE, WEAKENS JOINTS, & EVENTUALLY BURST PIPE. HYDRULIC SHOCK IS AN INTERNAL & IT OCCURS SUDDENLY WITHOUT NOTICE.

CAUSES OF SHOCK:

a. START / STOP OF PUMPS
b. IMPROPER CHECK VALVE
c. RAPID CLOSING of VALVES (LAST 15% of CLOSING ∝ SURGE PRESSURE)

t, TIME TO CLOSE QUICK VALVE = $\frac{2L}{a}$, L, LENGTH of PIPE (CLOSURE TO RELIEF POINT); a VELOCITY of PROPAGATION of ELASTIC VIBRATION IN PIPE)

$\frac{2L}{a}$, TIME TO TRAVE FROM POINT of CLOSURE TO RELIEF POINT & BACK TO POINT of CLOSURE

P = MAGNITUDE OF PRESSURE WAVE = $\gamma a \Delta V / 144 g$, Psi

$a = 4660 / [1 + KB]^{1/2}$; $K = \frac{E \text{ MODULUS ELASTICITY } H_2O}{E \text{ MODULUS ELASTICITY PIPE}}$

γ = SPECIFIC WT., PCF
ΔV = CHANGE IN VELOCITY, FPS
g = 32.2 Ft/Sec²
4660 = VELOCITY of SOUND IN WATER, fps
B = D_{PIPE} DIAMETER / t WALL THICKNESS

t_v = VALVE CLOSING TIME
t = INTERVAL TIME, FORWARD & BACKWARD

$t_v < t$ WHEN FLUID RETURN, VALVE CLOSED, MAJOR PRESSURE DAMAGE
$t_v > t$ WHEN FLUID RETURN, VALVE STILL OPEN LESS DAMAGE

K	PIPE MAT'L
0.020	CAST IRON
0.0170	COPPER
0.010	STEEL
0.017	BRASS
0.012	MALLEABLE CAST IRON

HYDRAULIC SHOCK SIMPLIFIED EQUATION PRESSURE INCREASE →

P (PSI) = 0.070 L (Ft PIPERUN) VELOCITY FPS / t VALVE CLOSURE TIME (S)

= 0.070LV/t

AIR CHAMBERS: SHOCK ABSORBERS, A PIECE OF SAME DIAMETER PIPE (12" TO 24") CAN BE USED AS WELL. OVER YEARS AIR CHAMBERS SHOWN FAILURE & USELESS. THEY MUST BE CORRECTLY SIZED (VOLUME OF AIR), SIZE AIR CHAMBERS, PERIOD OF PRESSURE, ... REQUIRED FOR SIZING.
INERT GAS/AIR CHAMBER WITHIN MEMBRANES WORK & ONCE SEALED AIR PRESSURE IS STABLE & DO NOT LEAK. EFFECTIVE OPERATION.

SWING VALVE IN DISCHARGE SIDE OF PUMPS: DURING PUMP SHUT DOWN, WATER REVERSAL CAUSE SLAM OF GATE CAUSING SHOCK WAVES.

SPRING VALVE TO BE USED & DESIGNED TO CLOSE EXACT MOMENT WATER FLOW CLOSES
NO CHANGE IN FLUID VELOCITY, THEREFORE:
NO HYDRAULIC SHOCK WAVE.

PIPE DAMAGES

OTHER THAN HYDRAULIC SHOCK, EROSION, NOISE, & CAVITATION ARE OTHER ISSUES.

CAVITATION: SPONTANEOUS VAPORIZATION OF FLUID IS BASED ON WHEN PRESSURE OF FLUID IS THE LESS THAN VAPOR PRESSURE OF THAT FLUID (WITHIN THERMODYNAMICS of FLUID). POCKETS OF VAPOR CREATED IS CALLED CAVITY THIS CAN OCCUR WITHIN PUMPS OR SOMETIMES UPSTREAM OF SUCTION SIDE OF PUMP, AS VAPOR CAVITY APPROACHES IMPELLER, NOISE, VIBRATION, IMPELLER PITTING, & STRUCTURAL DAMAGE OCCUR.
WITHIN PIPES, WHEN DIRECTION OF FLOW CHANGES SHARPLY & VELOCITY IS HIGH, CAVITATION OCCURS. SHORT RADUIS PIPES @ HIGH VELOCITY, CAUSES MAJOR CHANGE IN PRESSURE WITHIN FLUID, THUS CAUSING CAVITY. BUBBLES COLLAPSE DOWNSTREAM WITHIN PIPES.

NOISE: PART of HYDRAULIC SHOCK, CAVITATION CAN BE REDUCED BY LOWRING VELOCITY WITHIN PIPES

EROSION: PIPES DEPENDING ON MATERIAL, FLUID, SOLID CONTENT, TEMPERATURE, VELOCITY HAVE DIFFERENT EROSION ISSUES. PIPE ELBOWS, CONNECTIONS, SURFACE ROUGHNESS, CALCIUM BUILDUPS, ARE ALL FACTORS OF ABRASION PROCESS & EROSION. 5FPS & 8FPS ARE NOW LIMITS of HOT & COLD PIPE WATER VELOCITIES BY CODE.

REVISIONS

DATE: SHEET:
PROJECT:
SUBJECT:
RE:

HYDROMETER

SCOPE
BUDGET
CODES

PROJECT INITIAL TASKS

"SBCUSWG"

UTILITIES
SEWER
WATER
GAS

1. **SCOPE OF WORK:**
VARIES FOR ALL PROJECTS & "SCOPE CREEP" MAY BECOME MAJOR CONCERNS THROUGHOUT WORK

a. IDENTIFY & TRANSCRIBE CLEAR/STEPWISE SCOPE OF WORK & VERIFY WITH ALL FOR ITS ACCURACIES.
b. LIST & IDENTIFY ALL PLAYERS IN PROJECT
c. NOTIFY PARTIES (P.M., ETC.) ALL WORK BEYOND SCOPE OF WORK

2. **CONSTRUCTION BUDGET**
IDENTIFY THE TYPE OF BUILDING & PROVIDE $/SQFT OR COMPLETE CONSTRUCTION COST. ESTIMATING BOOKS MUST BE CURRENT & MATCH LOCALITIES (R.S. MEANS, ETC). BUDGET CONTROLS DESIGN

3. **A.H.J. (AUTHORITIES HAVING JURISDICTIONS), CODES, LAWS, GUIDELINES.**
FULL IDENTIFICATION OF ALL APPLICABLE LAWS IS CRITICAL. INDIVIDUALS ADMINISTERING ARE IMPORTANT: PLAN CHECKERS, INSPECTORS (PLUMBING, MECHANICAL, FIRE, HEALTH, WATER, SEWER, INSURANCE CO.; BUILDING, ...) THERE ARE MANY NATIONAL CODES IPC, UPC, APA, OSHA, IBC, AND MANY LOCAL CODES & AMENDMENTS.

4. **UTILITIES:** INVESTIGATE LOCAL CONDITIONS, CREATE UTILITY SITE PLANS WATER, SANITARY, STORM, GAS, ELECTRIC, TOPOGRAPHY (CONTOUR LINES), RIGHT-A-WAY'S (EASEMENTS), HARDSCAPE VS LANDSCAPES, CAPACITIES, SIZES, PRESSURES, MATERIALS. THIS MUST BE COORDINATED WITH CIVIL ENGINEER (IF AVAILABLE), ELECTRICAL & ALL UTILITY COMPANIES, PUBLIC WORKS, OR ANY OTHER AGENCIES. BACKFLOW DEVICES MAY APPLY.

5. **SEWER:** ALL OF #4 CONDITIONS APPLY. POINT OF CONNECTION, ELEVATION, SLOPES, LATERALS, MANHOLES, (INVERT, & TOP OF ELEVATIONS), LOADING CAPACITIES, POSSIBLE SURCHARGE ISSUES, THE LATERAL CONNECTIONS TO BUILDINGS,

6. **WATER:** ALL OF #4 CONDITIONS APPLY. METER, VALVES, BACK FLOW DEVICES, PRESSURES, CAPACITIES FOR FIRE, DOMESTIC USE,

7. **GAS:** ALL OF #4 CONDITIONS APPLY. METER, VALVE, PRESSURE, BTU CONTENT, P_{gas}, MATERIAL, ...

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REVISIONS

DATE: SHEET:
PROJECT:
SUBJECT:
RE:

DETAILS CIVIL . STRUCTURAL . ELECTRICAL . MECHANICAL . PLUMBING . ENERGY . LEED . GREEN ENGINEERING & CONSULTING

4" O.K.

CLEANOUTS: CLEANOUTS PIPES MATCH PIPE SIZE UP TO 4"Ø (6", 8", ...)
a. ANY change IN DIRECTIONS >45°
b. INSIDE/OUTSIDE BUILDING @ POINT of EXIT (WYE BRANCH OR House TRAP)
c. 50 ft OR MAX. DISTANCE 4" OR LESS, 100 ft FOR LARGER >4"Ø
>10"Ø REQUIRES MANHOLE @ every DIRECTION CHANGE OR 150 ft.
d. BASE of ALL STACKS.
PROPER ACCESS (18-24" CLEAR), FOR ROTO RODDERS, FIXTURE REMOVAL AS ACCESS TO CLEANOUT IS ACCEPTABLE.

WASTE:
INDIRECT WASTE: INDIRECT CONNECTION TO SANITARY
TRAPPED, VENTED. & DISCHARGE OUTLET SHOULD BE 1.5 TIMES INDIRECT PIPE SIZE ABOVE FLOOD LEVEL. CLEAN OUTS MANDATORY SINCE MANY BLOCKAGE BECAUSE of LOW VELOCITY & LOW FLOW.
INDIRECT WASTES: SINKS, LAVATORIES, CONDENSATE DRAINS.
EXTREME PNEUMATIC EFFECTS DUE TO LOW RATE of FLOW
SPECIAL WASTES
- TANK OVERFLOW, TANK EMPTYING line, Relieve VALVE DISCHARGE SHOULD BE INDIRECT WASTE DUE TO OVER PRESSURIZATION
- DISCHARGES WITH AIR BREAK (F.S, ROOF DRAIN, ...)
- SAME FOR COOLING JACKETS, DRIP ~~PANS~~ PANS, STEAM EXPANSION BOILER OVERFLOWS, ...

RATE of FLOW IN FIXTURES

RATE of FLOW = RATE of DRAINAGE
h = mean vertical height
$\dot{V} = q = 13.17\, d^2\, h^{1/2}$
gpm in ft

IN BRANCHES

- BRANCHES = Σ FLOW FIXTURES TO BRANCH
- UNIFORM FLOW
- BRANCH EXTENDED >5' DEV. LENGTH
- HYDROSTATIC PRESSURE = SURCHARGING
- IN SHORT RUNS, DUE TO HIGH VELOCITY SURCHARGE OCCURS
- BRANCH, q or $\dot{V}$ < STACK $\dot{V}$, q or House q, $\dot{V}$
- q. INTO STACK CANNOT DISTURB STACK
- Or Back PRESSURE INTO BRANCH
- STACK FLOW MAX = $\Sigma\, q_{STACK} + q_{BRANCH}$

SCOURING: TO INSURE SAND, GRIT, PEBBLES, & OTHER SOLIDS ARE IN SUSPENSION, THE FLUID FLOW MUST BE AT MINIMUM TERMINAL VELOCITY. THIS WILL INSURE NO WASTE DEPOSITION & BLOCKAGE. 2FPS IS MINIMUM & 4FPS MINIMUM FOR GREASY CONTENT FLUID FOR 2" & 1½" PIPE WITH FULL OR ½ FULL FLOW FLOW VELOCITIES IN DRAINAGE PIPING ARE 1.98 & 1.85 FPS (LESS THAN 2FPS). MINIMIZE LENGTHS OF 1½" & 2" PIPE.

SURCHARGING

TO ACCOMODATE OVERFLOW OR CERTAIN PEAK LOADS, OR WHEN SEWER & STORM DRAINAGE ARE COMBINED, SURCHARGING IS POSSIBLE EVENT & MUST BE ACCOUNTED FOR.

VERTICAL DISTANCE WITHIN MANHOLE IS MEASURE OF SURCHARGING. THIS MEASURE IS THE LEVEL ABOVE GRAVITY "FULL FLOW" CONDITIONS. OPTIONS: SMALLER PIPE USED FOR NORMAL CONDITIONS & LESS SLOPE TO MEET TOPOGRAPHY. SURCHARGE IS ALLOWED OVER CAPACITY FOR ABNORMAL CONDITIONS.

SEWER SHAPES.

VARIABLE PIPE SHAPES WILL ALLOW HIGHER TERMINAL VELOCITY IN LOW FLOW CONDITIONS & @ HIGHER FLOW RATES, THE VELOCITY COULD REMAIN THE SAME $V = Q/A$ AS Q↑ INCREASE, A↑ INCREASES HYDRAULIC RADIUS INCREASES

SANITARY SEWER: PUBLIC (WHEN AVAILABLE) & PRIVATE. IN ALL CASES FULLY CONTAINED & NEVER @ HUMAN REACH. NEVER MIX WITH STORM WATER UNLESS FULLY TREATED

COMBINED SEWER & STORM SYSTEM: NOW EXTREMELY RARE, ALL COMBINED NOW MUST BE TREATED BEFORE REUSE OR DISCHARGE. STORM SOMETIMES USED AS OVERLOAD INTO SEWER SYSTEMS.

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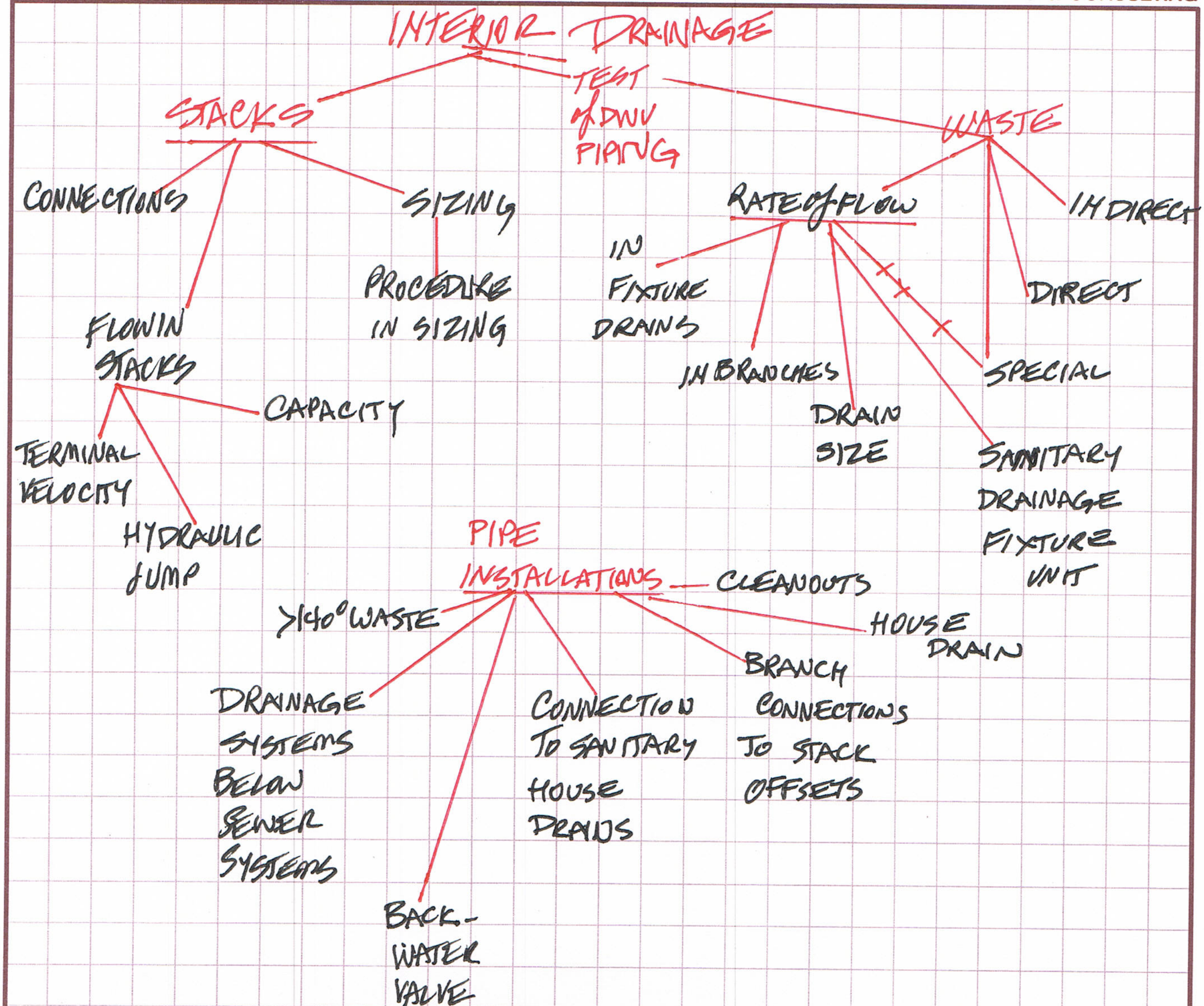

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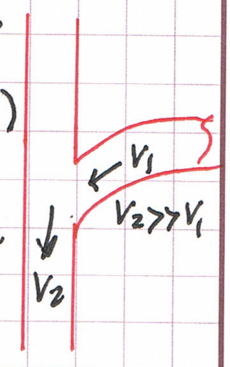
STACKS

VERTICAL SEWER PIPING COLLECTS HORIZONTAL BRANCHES

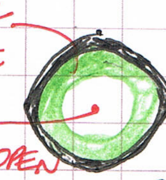
"SOIL" STACK: FECAL MATER (WATER CLOSET) & URINALS
"WASTE" STACK: SHOWER, SINKS, LAVATORIES

CONNECTIONS: HORIZONTAL TO VERTICAL (SAINTARY TEE)
VERY HIGH VELOCITIES CREATE SELF SIPHONIC OF TRAPS.
TEE-WYE = "SAME" AS: "COMBINATION WYE" & "ONE EIGHTH WYE"
SANTARY TEE: ONLY IN VERTICAL POSITION
TEE WYE : IN ANY POSITION



FLOW IN STACKS: FEARS ARE: HIGH VELOCITY CAUSING UNWANTED IMPACT FLOW, SLUG OR FULL FLOW CAUSING SIPHONAGE & SUCTION OF WATER IN TRAPS, CREATION OF PRESSURE FLUCTUATIONS DUE TO PLUG FLOW (MAX ± 1" H_2O)

SHEET of WATER 1/4 TO 1/3 of PIPE AREA



CORE 3/4 or 2/3 OPEN

TERMINAL VELOCITY

GRAVITATIONAL FLOW WILL REACH EQUILIBRIUM WITH WALL FRICTIONAL FORCES (ASSUMING NO ADDITIONAL FLOW IS ADDED), @ THIS STAGE VELOCITY REMAINS RELATIVELY CONSTANT OR "ULTIMATE" VELOCITY OR TERMINAL VELOCITY. WHICH IS ACHIEVED @ "TERMINAL LENGTH" $V_T \approx 10 \to 15$ FPS WITHIN $L_T \approx 10 \to 15$ FT
THEREFORE V_T IS IRRESPECTIVE of L_T
& WITHIN 3 STORY SAME BEHAVIOR AS 50 STORY

V_T (TERMINAL) $= 3\left(\frac{\dot{V}}{d}\right)^{2/5}$

L_T (TERMINAL) $= 0.052\, V_T^{2}$

$\dot{V} = q =$ FLOW RATE
$d = D =$ STACK DIAMETER

CAPACITY of STACKS

PLUG / SLUG FLOW DOES NOT OCCUR TILL $A_F = \left(\begin{matrix}1/4 \\ 1/3\end{matrix}\right.$ of $\left.A_{TOTAL}\right)$

$q_{MAX} = \dot{V}_{MAX} = 27.8\, r^{5/3} d^{8/3}$

r = AREA OF FLOW / AREA of PIPE

MAXIMUM CAPACITY of STACKS (GPM)

PIPE	(r 1/4)	r 7/24	(r 1/3)
2	18.5	23.5	—
3	54	70	85
4	112	145	180
6	330	435	530
8	710	920	1145
10	1300	1650	2055

UPPER LIMIT DIAPHAGMING

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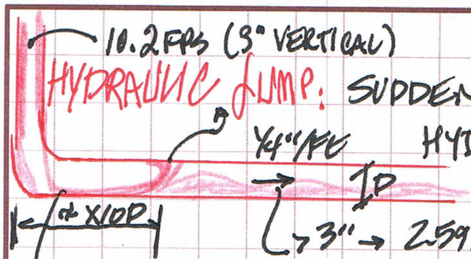


HYDRAULIC JUMP: SUDDEN TRANSITION OF VERTICAL TO HORIZONTAL MAY CAUSE HYDRAULIC JUMP

CRITICAL VELOCITY
"d" DEPTH REDCES THEN INCREASES TO — SUDDEN RIZE IN DEPTH = HYDRAULIC JUMP

ANY OFFSETS ~~45~~ DEGREES CREATES HYDRAULIC JUMP

DISTANCE of OCCURANCE of HYDRAULIC JUMP = f(ENTRANCE VELOCITY, DEPTH of HORIZONTAL WATER, PIPE ROUGHNESS, PIPE DIAMETER, SLOPE)

JUMP REDUCES WHEN PIPE DIAMETER, SLOPE, & PIPE ROUGH. INCREASE

SURGING DIES WITH PIPE ROUGHNESS

HIGH TEMPERATURE WASTE: HIGH TEMPERATURE CAUSES PIPE EXPANSION. EXCESSIVE CONTRACTION & EXPANSION WILL DAMAGE PIPES. BOILERS, RESTAURANT DRAINS MUST BE COOLED BELOW 140°F BEFORE DISCHARGING. THIS CAN BE DONE AS ENERGY CONSERVATION TECHNIQUE AS WELL.

DRAINAGE BELOW SEWERLINES: VERIFY ALL OPTIONS BEFORE DESIGNING UNDER SUCH CONDITIONS. EJECTOR/PUMPS ARE REQUIRED (TIGHT & VENTED) CONDITIONS.

BACKWATER VALVE. SEWER BACKWATER VALVES OCCUR WHEN STREET SEWER SYSTEM IS CLOGGED & BUILDING IS FLOODED WITH PUBLIC SEWAGE. ONE BACKWATER VALVE TO SERVE UNITS LOWER THAN SEWER PIPE IS REQUIRED. OTHER FLOORS NOT EFFECTED WILL BE SEGREGATED WITH INDEPENT MAIN SEWER CONNECTIONS.

HOUSE DRAINS TO FLOW 1/2 TO 2/3 FULL FLOW @ PEAK
BRANCH CONNECTIONS @ UPPER-HALF OF PIPE (AIR SPACE PORTION)

a. LOWER CHANCE of STOPPAGE @ BRANCH
b. LESS FLOW INTERFERENCE @ POC
c. WHEN NO FLOW IN BRANCHES, FULL AREA of PIPE TO RELIEVE PNEUMATIC PRESSURE FLUCTUATIONS.

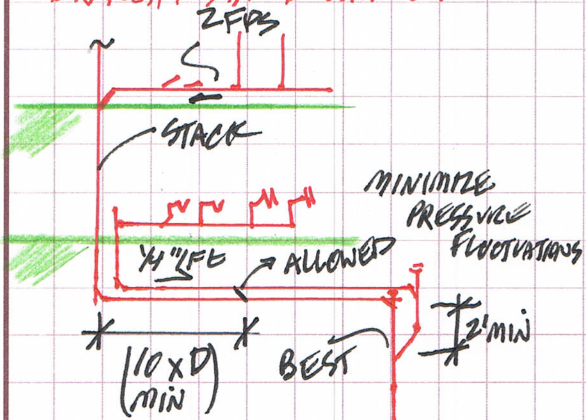
PIPE INSTALLATION

- 2FPS, 1/4"/FT FOR 3"ϕ OR SMALLER
- FOR LARGER > 3"ϕ, 1/8" MAY BE FINE
- ALL CONNECTIONS TO HORIZONTAL: 90° ELBOWS, TEES, SANITARY TEES, TEE-Y'S @ 1/4"/FT
- DON'T INSTALL SEWER PIPING OVER EQUIPMENT WHERE LEAKAGE OR CONDENSATE MAY OCCUR (Electrical !...)
- IF NOT POSSIBLE TO REROUTE, CONDENSATE PLATES TO BE COLLECT. ANY CONTAMINANTS (PAN ~~[struck out]~~) N/G
- UNDERGROUND (FIRM BED) WITH ALLOWANCE FOR BELL CONNECTIONS.
- CLEANED EARTH OR SCREENED GRAVEL UNDER, TOP of PIPE TO 1FT ABOVE, BACKFILL & COMPACT EVERY 24" (90%) & 95% UNDER FLOOR

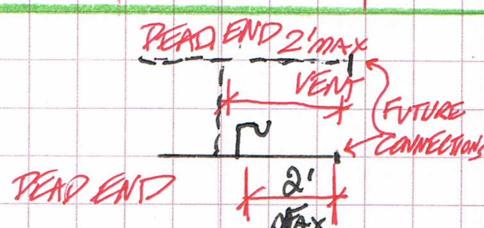
FULLY COMPACTED 90%

- TURNS MUST NOT CAUSE MAJOR FRICTIONS
- SHORT TURNS ONLY OK IN VERTICAL RUNS
- DOUBLE SANITARY (VERTICAL) SHOULD NEVER BE INSTALLED
- NEVER CROSS FLOWS
- ANY DOUBLING of FITTINGS PROHIBITED
- DEAD ENDS CREATE FUNGI, SLIME, SLUDGE
- ONLY CLEANOUTS - DEAD END

BRANCH / STACK CONNECTION



PIPE SUPPORT	HORIZ.	VERT.
CAST IRON SOIL	EVERY FITTING & EVERY JOINT	EVERY STORY
SCREWED PIPING	EVERY 12'	ALTERNATE FLOORS
DWV COPPER	10' O.C. 2"ϕ < 6' O.C. ≤ 2"ϕ	EVERY STORY



DOMESTIC WATER

SUBJECT IS USED IN PLUMBING, MECHANICAL, CIVIL, & CHEMICAL ENGINEERING. RE > 4000 - TURBULENT, & 2000 < Re < 4000 LAMINAR FLOW OCCURS WHEN MEASURING OR CALCULATING $Re = \frac{DV\rho}{\mu} = \frac{DV}{\nu}$

TURBULENT FLOW OCCURS 1/2", 1", 2" PIPES
V > 0.676, 0.338, 0.169 FPS @ 50°F
V > 0.247, 0.124, 0.0617 FPS @ 140°F

WATER HAMMER: A SYMPTOM OF HYDRAULIC SHOCK

HYDRAULIC SHOCK: SUDDEN & RAPID CHANGE IN VELOCITY
CAUSES: QUICK CLOSING VALVE

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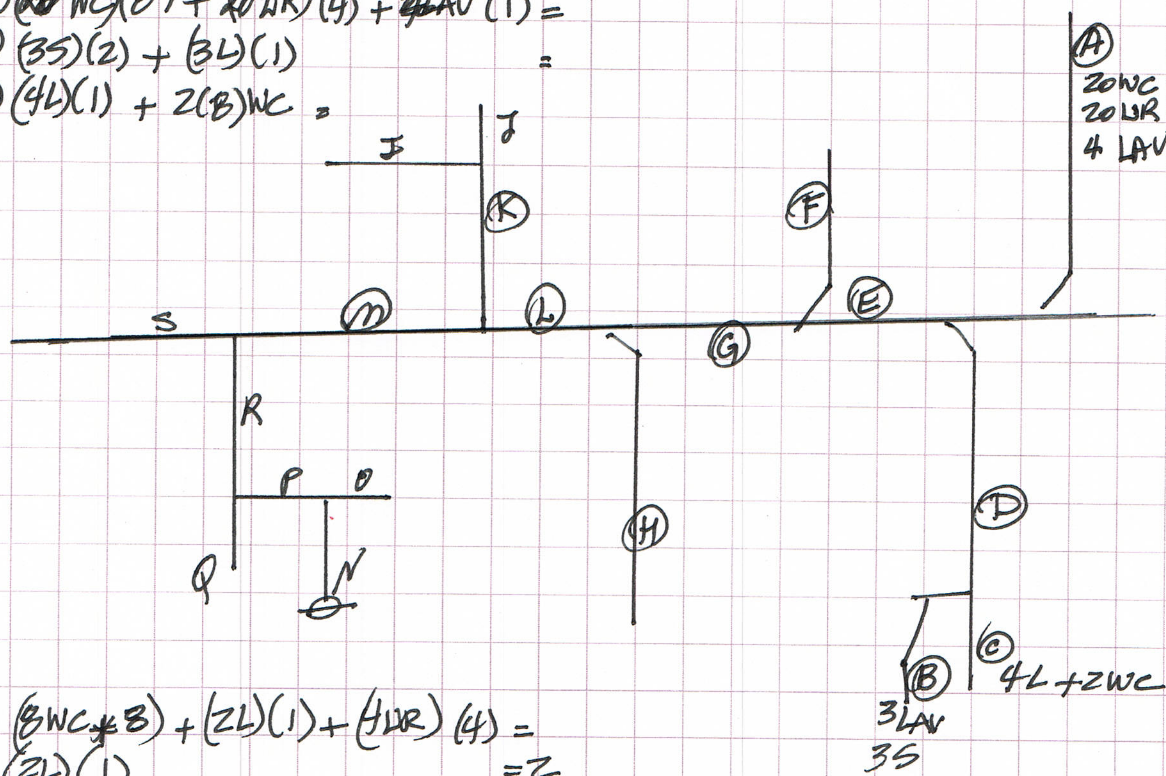
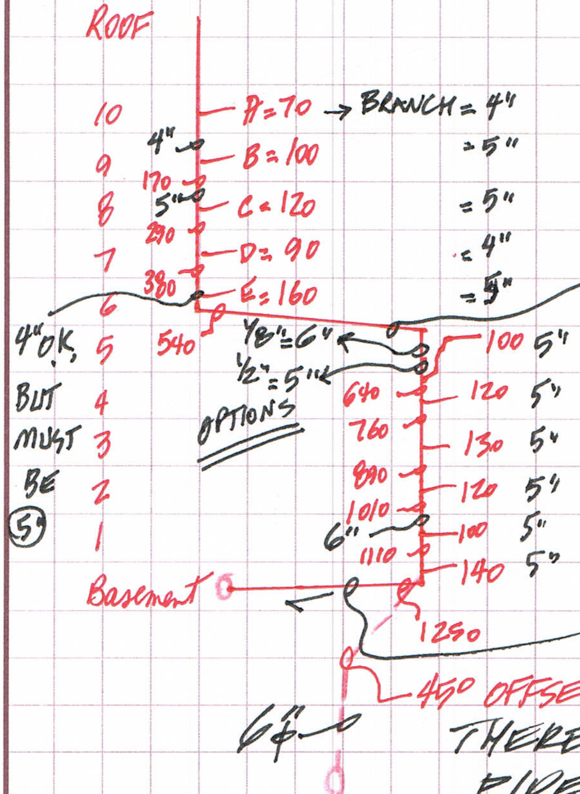
HOUSE DRAINAGE

(A) (20 WC)(8) + (20 UR)(4) + 4 LAV (1) =
(B) (3S)(2) + (3L)(1) =
(C) (4L)(1) + 2(B)WC =



(F) (8WC*8) + (2L)(1) + (4UR)(4) =
(H) (2L)(1) =2
(N) CLEAN OUT
(O) (3BT)(2)+(3SH)(2)+(2WC)(8)=
(J) (2BT)(3)+(2L)(2) =
(I) (3WC)(8)+(2SK)(2) =
(Q) 8(3WC)+(2SK)+(2L)(2) =

STACK SIZING



1/8" = 700, 6"
1/4" = 840, 6"
1/2" = 1000, 6"

5", 1/8" = 390
5", 1/4" = 480
5", 1/2" = 575

6" Cannot work

OPTIONS: 8" minimum Regardless of slope

45° OFFSET ASSUMES STILL VERTICAL THEREFORE No change in VERT. to HORIZ. PIPE 6"Φ OK.

HOUSE DRAIN SIZING

1/2 CAPACITY to 3/4 MAX. (To PREVENT FLUCTUATIONS)
1/4"/Ft FOR <3"Φ, & 1/8" >3"Φ O.K. 1/16"/Ft for 6"Φ < O.K.

	1/16"/Ft	1/8"/Ft	1/4"	1/2"
2 1/2Φ	1.02	1.44	2.03	2.88
3	1.24	1.76	2.49	3.53
4	1.44	2.03	2.88	4.07
5	1.61	2.28	3.53	4.56
6	1.76	2.49	4.07	5.0
8	2.03	2.88	4.23	5.75
10	2.28	3.23	4.56	6.44

Sump Pump @ 200GPM = 2×200 = 400 F.U.

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FIXTURES

F. DRAIN SIZE
BASED ON MIN TRAP SIZE

SANITARY FIXTURE UNIT (FU)
ROY HUNTER BMS (1940)
- UNITS ASSIGNED TO DIFFERENT FIXTURES (1923)
- BASED ON PROBABILITY OF USE BASE ON CUMULATIVE F.U.'S (NOT GPM)

1 F.U. = 7.5 G/FT3 FACTOR
= TOTAL GPM OF FIXTURE / 7.5 GAL/FT3
= FLOWRATE (P?)

- PRIMARY REASON TO CUMULATIVE LOADING IN FU'S

STACK SIZING IN FU

$q = 27.8\, r^{5/3} d^{8/3}$

MAX. FU FOR STACKS (r = 7/24)

⌀	FU (3 STORIES OR LESS)	>3 STORIES	TOTAL DISCHARGE 1 BRANCH
2" ⌀	10	24	6
2 1/2	20	42	9
3	30*	60*	16+
4	240	500	90
5	540	1100	200
6	960	1900	350
8	2200	3600	600
10	3800	5600	1000
12	6000	8400	1500

* NOT MORE THAN 6 W.C.
+ NOT MORE THAN 2 W.C.

$\left[r = A_W / A_T = 7/24 \right]$

$q = \dot{V} = 27.8\, r^{5/3} d^{8/3} = 27.8 \,(7/24)^{5/3} (4)^{8/3} = 145\ GPM$

MAX. LOADING = 145 GPM, r = 7/24, >3 STORIES, 4", 500 FU

MAX FU	SANITARY BRANCHES
1 1/2" ⌀	F.U. 3
2	6
2 1/2"	12
3"	20 * <2 W.C. MAX.
4"	160
5"	360
6"	620
8"	1400

2 F.U. = 1 GPM

MAX. F.U. SANITARY BUILDING & RUNOUTS FROM STACKS

PIPE ⌀	SLOPE in/FT 1/8"	1/4	1/2"	
2	–	21	26	26
2 1/2	–	24	34	31
3	20	27	36	36
4	180	216	250	250
5	390	480	5[illegible]0	575
6	700	840	2000	1000
8	1600	1920	2300	2300
10	2900	3500	4200	4200
12	4600	5600	6700	6700
15	8300	10,000	12000	12000