FERMILAB ENGINEERING NOTE	SECTION PPD/MD	PROJECT COUPP	SERIAL-CATEGORY E-961	PAGE 1
SUBJECT MAXIMUM FLOWRATE OF CF_3I UP TUBE		NAME RUSS RUCINSKI		
		DATE 7/23/09	REVISION DATE	

$$\Delta P = 3.36\times10^{-6}\,\frac{f L W^2}{\rho d^5}$$

CRANE TECH. PAPER #410 EQN 3-5.

1" OD TUBE, RA-20 ON INSIDE, VERY SMOOTH × .065 WALL × 26.5" LG.

$\varepsilon/D = .0006$ PG. A-23 CRANE TECH PAPER 410

ASSUME $Re \approx 10^6 \Rightarrow f = 0.0115$ CAN CHECK AFTER CALCULATION.

$\Delta P = 106\ \text{PSIA} - 15\ \text{PSIA} = 91\ \text{PSID}$

$L = 26.5''/12''/\text{ft} = 2.21$

$d = .87\ \text{IN}$

REF PROP BY NIST

$\rho\,(T = 40°C, \bar{P} = 60\ \text{PSIA}) = 33.9\ \text{kg/m}^3 = 2.12\ \text{lbm/ft}^3$

REARRANGING EQN 3-5 TO SOLVE FOR W

$$W = \left[\frac{\Delta P\,\rho\,d^5}{3.36\times10^{-6}\,f L}\right]^{1/2} = \left[\frac{(91\ \text{psi})(2.12\ \text{lb/ft}^3)(.87\ \text{in})^5}{3.36\times10^{-6}(.0115)(2.21)}\right]^{1/2}$$

$W = 33556\ \text{lb/hr}$

20°C, 0.101 MPa

$$q_m' = 33556\ \text{lb/hr} \times \frac{1\ \text{hr}}{60\ \text{min}} \div \left[\left(8.366\ \frac{\text{kg}}{\text{m}^3}\right)\left(.06248\ \frac{\text{lb/ft}^3}{\text{kg/m}^3}\right)\right]^{-1}$$

$q_m' = 1070\ \text{scfm}^*$ — * NOT POSSIBLE, EXCEEDS VELOCITY OF SOUND SEE NEXT PAGE

CHECK Re ASSUMPTION

$Re = 6.31\ W/d\mu$ EQN. 3-3 CRANE TECH. PAPER 410

$\mu = 15.00\ \mu\text{Pa-s}$ 40°C 60 PSIA

$$Re = 6.31\,\frac{(33556\ \text{lb/hr})}{(.87\ \text{in})(15\ \mu\text{Pa-s})} \times \frac{1\ \mu\text{Pa-s}}{10^{-3}\ \text{cP}}$$

$Re = 16\times10^6 \Rightarrow f = 0.008$

$W = 40{,}230\ \text{lb/hr}$ $\boxed{q_m = 1283\ \text{scfm}}$ *

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CHECK FOR CHOKED FLOW.

$v_s = 114\ m/s$ SPEED OF SOUND $T = 40°C$ $P = .4\ MPa$ (60 PSIA)

$$Q_{MAX} = v_s \cdot A_{TUBE} = 114\ m/s \times \frac{\pi}{4}(.87\ in)^2 \times \left(\frac{.0254\ m}{in}\right)^2 \times \frac{60\ s}{min} \times \frac{35.3\ ft^3}{1\ m^3}$$

$$= \underline{92.6\ ft^3/min}$$ @ FLOWING CONDITIONS.

FOR $P = P_{SAT} = 0.711\ MPa$, $T = 40°C$ $v_s = 106\ m/s$

$$q'_m = 86.1\ ft^3/min \times \left[\frac{8.366\ kg/m^3}{66.5\ kg/m^3}\right]^{-1}$$

$$\frac{\rho_{STD\ CONDITIONS}(.10\ MPa, 20°C)}{\rho(.711\ MPa, 40°C)}$$

$$\boxed{q'_m = 684\ scfm}$$

- MAXIMUM FLOW OUT OF 1/4" OD. x .035" WALL TUBING (.18 IN ID)

$$q_{MAX} = q'_m \times \left[\frac{(.25 - .07\ in)}{.87\ in}\right]^2 = \boxed{29.3\ scfm}$$

- MAXIMUM FLOW OUT VALVE WITH $C_V = 0.3$

MD-250 $C_V = 0.3$, SWAGELOK DIAPHRAGM HP VALVE, $C_V = 0.2$

$\Delta P = 0.425\ MPa - 0.101325\ MPa$

SAT. PRESSURE AT 20°C

$\Delta P = 62\ PSIA - 15\ PSIA = 47\ PSI$

THE OUTLET PRESSURE IS < 53% P_1 ∴ CRITICAL FLOW

$$C_V = q\ \frac{[SG\ (T+460)]^{1/2}}{660\ P_1}$$

$\rho_{GAS} = 38.4\ \frac{kg}{m^3}$ $T = 20°C$

$$q = \frac{660\ P_1}{C_V\ [SG \cdot (T+460)]^{1/2}}$$

$\rho_{N_2} = 1.165\ \frac{kg}{m^3}$ $T = 20°C$

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$$Q_h = \frac{660\,(62\ \text{psia})}{(0.3)\left[33\,(60+460)\right]^{1/2}} = 1041\ \text{ft}^3/\text{hr}$$

$$q_m = \underline{17.4\ \text{scfm}}$$

CALCULATE AMOUNT OF TIME TO RELEASE ALL CF_3I AT THESE FLOW RATES.

AMOUNT OF $CF_3I = 9.5\ m^3 = 335.5\ ft^3$

FLOW RATE (scfm)	TIME OF RELEASE (MIN)
17.4 scfm	19.2 MINUTES
29.3	11.5 MINUTES
684	0.5 MINUTES

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SUBJECT: CF_3I MIXING, REYNOLDS #	NAME: RUSS RUCINSKI			
	DATE: APR. 27, '10	REVISION DATE		

CHECK TO SEE IF MIXING OF CF_3I OR STRATIFICATION IS MORE LIKELY.

CF_3I S.G. = 6.9 MAX. RELEASE RATE = 684 scfm

(REF. OTHER CALCS. THIS NOTE)

CALCULATE A REYNOLDS NUMBER FOR A SUBMERGED PLANE JET OUT OF A LONG NARROW SLOT[1]

$$Re = \frac{U_0 (2b_0)}{\nu}$$

U_0 = VELOCITY

$2b_0$ = SLOT WIDTH

ν = KINEMATIC VISCOSITY = μ/ρ

LET THE SLOT WIDTH = 5% OF THE TANK PERIMETER

$$2b_0 = 0.05\,\pi(D) = .05(\pi)(102\,in)\left(.0254\,\frac{m}{in}\right) = 0.41\,m$$

$$U_0 = \frac{Q}{A} = \frac{684\ ft^3/min}{(.41\,m)(.0005\,m)} \times \left(\frac{1\,m}{3.28\,ft}\right)^3 \times \frac{1\,min}{60\,s} = 1575\ m/s$$

ASSUME 0.5 mm CRACK.

SURPRISINGLY HIGH.

$\mu = 13.85\ \mu Pa\text{-}s$

NOTE: $\nu = \frac{\mu}{\rho}$

$$Re = \frac{(1575\ m/s)(0.41\,m)}{\left[\frac{13.85\times10^{-6}\ \frac{N}{m^2}\cdot s}{8.24\ \frac{kg}{m^3}}\right]} \times \left[\frac{1\,N}{\frac{kg\,m}{s^2}}\right]$$

$\rho_{CF_3I\ VAPOR\ 20°C\ 1\,ATM} = 8.24\ kg/m^3$

$\rho_{air} = 1.19\ \frac{kg}{m^3}$

$Re = 3.8\times10^8$ HUGE, TURBULENT. $SG_{CF_3I} = 6.9$

THE FLOW FIELD WILL ENTRAIN SIGNIFICANT SURROUNDING AIR INTO THE FLOW

1 BLEVINS, ROBERT D. "APPLIED FLUID DYNAMICS HANDBOOK" KRIEGER PUBLISHING CO., FLORIDA, 1992.

SUBJECT: CF_3I MIXING, SPECIES CONCENTRATION IN SPACE

NAME: RUSS RUCINSKI

DATE: 4-27-10 | REVISION DATE:

FOR PLANE JET, SUBMERGED TURBULENT JET, TABLE 9-3 EQUATIONS APPLY.

WIDTH $b = .11x$ WHERE x = AN AXIAL DISTANCE FROM NOZZLE EXIT

$b = .21\,m$, $\Rightarrow x = \frac{b}{.11} = \frac{.21\,m}{.11} = 2\,m$

SPECIES CONCENTRATION WIDTH, $b_{\Delta T} = .14x = .14(2) = .28\,m$

FIG. 9.8 SHOWS $\frac{\Delta T}{\Delta T_m}$ FOR DISTANCE TRAVERSED BY THE JET.

SPECIES CONCENTRATION AT LOCATION RELATIVE TO MEAN CONCENTRATION AT CENTER EXIT OF NOZZLE.

FOR $\frac{\Delta T}{\Delta T_m} = 0.05$ i.e. 5% CF_3I

$y/b = 2.5$ $\quad y = 2.5(b) = 2.5(.28\,m)$

$y = 0.70$ METERS $= 2.3$ ft.

$\Rightarrow$ THE CF_3I STREAM EXITING THE TANK DROPS FROM 100% CF_3I AT THE TANK LID TO 5% CF_3I ABOUT 2.3 FEET AWAY.

CALCULATE REYNOLDS # FOR A 29 SCFM RELEASE RATE FOR SUBMERGED TURBULENT JET

$$Re = \frac{u_m d}{\nu} \quad \& \quad u_m = \frac{Q}{A} = \frac{Q}{\frac{\pi d^2}{4}}$$

SUBST.

$$Re = \frac{Q\,d}{\nu \frac{\pi d^2}{4}} = \frac{4Q}{\nu \pi d}$$

$$= \frac{4\left(29\,ft^3/min\right)\left(\frac{1\,m}{3.28\,ft}\right)^3 \times \frac{1\,min}{60\,s}}{\left[\frac{13.85\times10^{-6}\,\frac{N}{m^2}\,s}{8.24\,kg/m^3}\right]\pi\left[.5\,in\right]\left[.0254\,m/in\right]}$$

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CF_3I MIXING, REYNOLDS #.	R. RUCINSKI	
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Re # = 317,000 WHICH IS TURBULENT

⇒ FOR A 24 cm RELEASE PIPE, TURBULENT MIXING AND AIR ENTRAINMENT WILL OCCUR.