Project: PS-TGT-14-001 Hall A Tritium Target

Tittle: Vent stack general calculations for air flow only

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Code(s) of Record:

Reference Codes:
ASHRAE Handbook
Crane 410 (2013)

Description:
General calculations for the T2 vent stack pressure drop and blower capacity

Reference Drawing(s):
Hall A HVAC system
Hall A Tritium Exhaust Sytem Schematic
TGT-103-1001-0000

Units and other definitions

$inH2O := 0.0381396333 \cdot psi$ def of one in of H2O

$g := 9.8 \cdot \frac{m}{s^2}$ grav accel

$k := 1.4$ ratio of specific heat

General Description:

The vent stack shall serve 3 purposes:

1. Remove vacuum pump exhaust to atm
2. Remove air from T2 handling enclosure
3. Remove air from Hall A durring an assumed T2 release

The required stack height is 20m above the surrounding site elevation. The stack shall be located on the vehical sevice access on the downstream exterior of Hall A at the smoke removal system penetration closest to the counting house. This location is about 26ft above Jefferson Ave. Thus, the required height of the stack above grade is ~40 ft.

The stack has two sections:

1. Vaccum exhaust is NPS 2" N2 purged with ~1 scfm
2. large volume air exhaust (two speed) NPS 16"

Section 2) requires a two speed blower. Low speed will service the T2 handling enclosure at 1000 scfm. The high speed must change operate at 12000 scfm for both smoke removal (in event of fire) and also for possible T2 release. If a T2 release is suspected this one blower must run at ~12000 scfm and stack the air removed from the hall. For smoke removal, the blower must work in concert with the other (2) blowers to remove the air from the hall at a combined 36000 scfm.

Truck ramp door:

The truck ramp door can sustain a 20 psf design load max. The pressure drop across the man door portal shall be less than this.

$$P_{roll} := 20 \cdot psf = 3.642\ inH2O$$

Handling hut:

The handling hut shall be attached to the scattering chamber via an adapter with and opening of 15" x 36". From private communication with Greg Howard at SRSTE and others, containment can be affected by ensuring the face velocity at an opening is about 140 ft/min. This is similar to those found in Cadwallader INEEL/EXT-99-01318. This shall be assured by measurements after installation. Air shall be removed from the hut through the scattering chamber at the port directly above the hut placement. Air flow shall be metered here by use of a manually controlled vacuum gate valve which enables easier closing of the scattering chamber once the T2 cell is completely installed.

$v_{req} := 140 \cdot \frac{ft}{min}$ required face velocity

$L_{open} := 36 \cdot in$ scattering chamber opening

$h_{open} := 15 \cdot in$ scat chamb height

$A_{open} := L_{open} \cdot h_{open} = 3.75\ ft^2$ x area of opening

$Q_{air} := v_{req} \cdot A_{open} = 525\ cfm$ volumetric air flow required

The low speed setting on the exhaust system shall be 1000 scfm. Too much flow through the hut may cause a turbulent condition and allow mixing and eddying at the scattering chamber opening defeating the containment.

The blower must supply at least 12000 scfm for smoke removal. This must be done through the stack. The blower must have the capacity to supply this flow and the expected pressure drop through:

- Stack: 50 ft of NPS 16 (0.25" wall)
- ductwok through Hall A wall
- Shutter opening at Hall A wall
- Man access door shutter at truck ramp
- Smoke removal port for truck ramp

Pressure drop in vertical stack of 40 ft in length.

$T_{air} := 0\ °C = 273.15\ K$	assumed air temperature
$M_{dry} := 28.96 \cdot \frac{gm}{mol}$	molar mass of dry air
$M_{H2O} := 18 \cdot \frac{gm}{mol}$	molar mass of H2O
$P_{air} := 1 \cdot atm$	air pressure
$\phi := 80\%$	humidity
$R_{dry} := \frac{R}{M_{dry}}$	R for dry air
$R_{H2O} := \frac{R}{M_{H2O}}$	R for water
$T := \frac{T_{air}}{K} = 273.15$	air temperature

Below is used to calc air density under normal humidity in NN Va From ASHRAE Handbook

$$P_{sat} := \frac{\exp\left(77.345 + 0.0057 \cdot (T) - \frac{7235}{T}\right) \cdot Pa}{(T)^{8.2}} = 0.088\ psi$$

$P_{H2O} := \phi \cdot P_{sat}$

$P_{dry} := P_{air} - P_{H2O} = 14.625\ psi$

$\rho_{air} := \frac{P_{dry}}{R_{dry} \cdot T_{air}} + \frac{P_{H2O}}{R_{H2O} \cdot T_{air}} = 0.081\ \frac{lb}{ft^3}$ density of air

$Q_{air} := 12000 \cdot cfm$ volumetric air flow

$L := 50 \cdot ft$ length of duct

$t_{wall} := 0.25 \cdot in$ wall of duct

$OD := 16 \cdot in$ OD of duct

$d := OD - 2 \cdot t_{wall} = 15.5\ in$ ID of duct

$A_{duct} := \frac{\pi \cdot d^2}{4}$ x area of duct

$v_{air} := \frac{Q_{air}}{A_{duct}} = 152.63\ \frac{ft}{s}$ velocity of air in duct

$Re := 8.5 \cdot \frac{d}{in} \cdot \frac{v_{air} \cdot min}{ft} = 1.207 \cdot 10^6$ Reynolds number for air at room temp/pressure

$f := \frac{0.032}{\left(\frac{d}{in}\right)^{\frac{1}{3}}} = 0.013$ simplified model of friction factor

$L_{eff} := 60 \cdot d$ conservative estimate for bends effective length

ΔP in stack

$$\Delta P_{stack} := \frac{\rho_{air} \cdot v_{air}^2}{2} \cdot f \cdot \frac{L + L_{eff}}{d} + \rho_{air} \cdot g \cdot L = 7.456 \ inH2O$$

Louvered intakes on the door and wall of Hall A

$h_L := 72 \cdot in$	height of louver open
$w_L := 24 \cdot in$	width of louver open
$\psi := 0.5$	eff area fraction
$A_L := h_L \cdot w_L \cdot \psi = 6 \ ft^2$	area of louver open
$v_L := \frac{Q_{air}}{A_L} = 22.727 \ \frac{mi}{hr}$	vel at opening

Determining the pressure drop across a louvered door is difficult to perform accurately. The method from Crane 410 for orifice is used with the assumption that the large diameter near infinite and $\beta := 0$

$\beta := 0$	ration of diameters
$P_{hall} := 14.6 \cdot psi$	assumed pressure in hall
$P_{atm} := 14.7 \cdot psi$	assumed air pressure
$Y := 1 - 0.351 \cdot \left(1 - \left(\frac{P_{hall}}{P_{atm}}\right)^{\frac{1}{k}}\right) = 0.998$	compress factor from Crane 410
$C := 0.5961$	discharge coef
$\Delta h := \frac{Q_{air}^2}{2 \cdot g \cdot (Y \cdot C \cdot A_L)^2} = 48.794 \ ft$	head loss at opening

$\Delta P_L := \rho_{air} \cdot g \cdot \Delta h = 0.715\ inH2O$

pressure drop over louvered opening

We note here that the pressure drop across the louvered opening is less than the maximum design load for the rollup door.

There is a short stack leading from the truck ramp to the the outside air. This stack is estimated at 30 ft length with a conservative diameter est. as that of the stack.

$L_{ramp} := 30 \cdot ft$

$$\Delta P_{ramp} := \frac{\rho_{air} \cdot {v_{air}}^2}{2} \cdot f \cdot \frac{L_{ramp}}{d} = 1.582\ inH2O$$

The total head loss for the system is

$$\Delta P_{total} := \Delta P_{ramp} + 2 \cdot \Delta P_L + \Delta P_{stack} = 10.468\ inH2O$$

The requried capacity of the blower is

$Q_{air} = \left(1.2 \cdot 10^4\right)\ cfm$ at $\Delta P_{total} = 10.468\ inH2O$