I. Overview (30 m)

a. Brief history, aerosol exposures

b. Equipment/animals

c. Class III cabinets

d. Procedural video

II. Aerosol generation (15 m)

a. Overview of generation technologies

b. Collison nebulizer

c. Viability

III. Sampling & characterization (15 m)

a. Methods of sampling (impinger, filter, etc.)

b. Particle sizing

c. Deposition and retention

IV. Dose (15 m)

a. Definition of dose

b. Calculation

c. Importance of the 'spray factor'

BREAK

V. Emerging Technology (30 m)

a. Genesis of the automated technology

b. Application

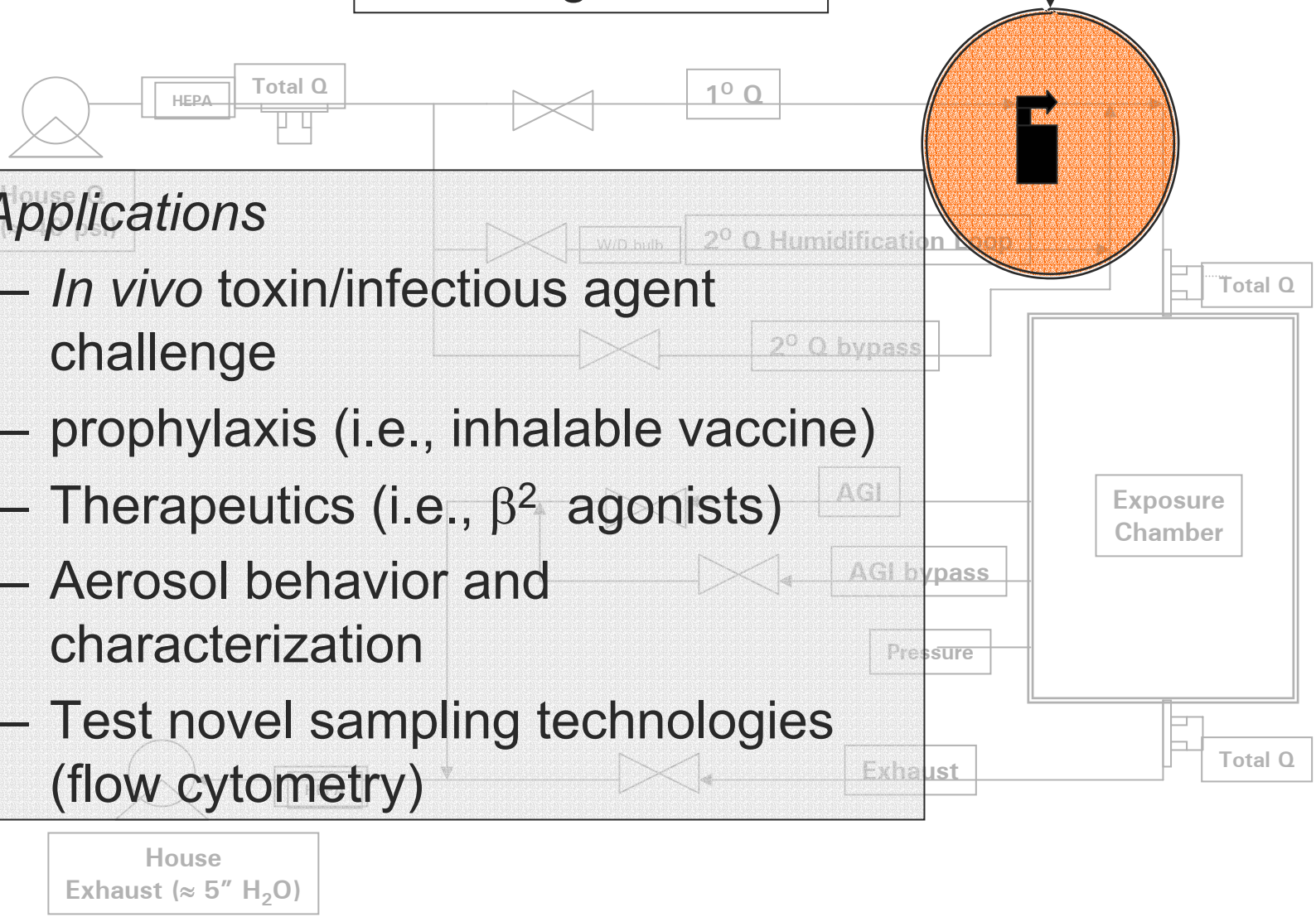
VI. Examples: aerosol exp. of animals (30 m)

a. Yersinia pestis

b. Bacillus anthracis

c. Staphyloccocal enterotoxin B

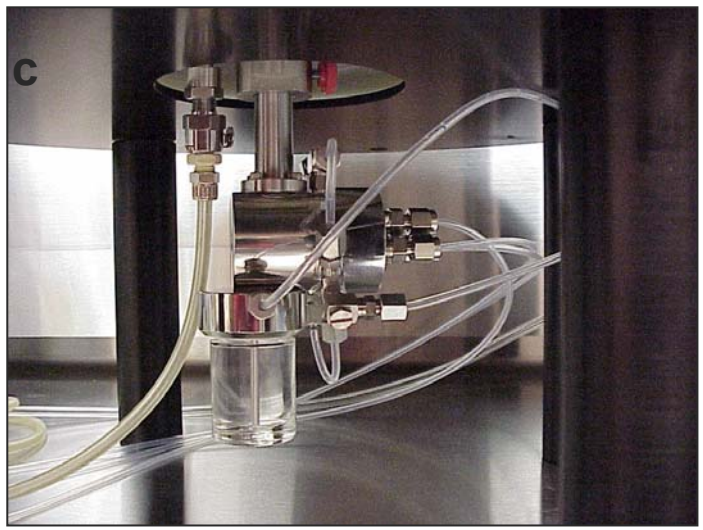
aerosol generation

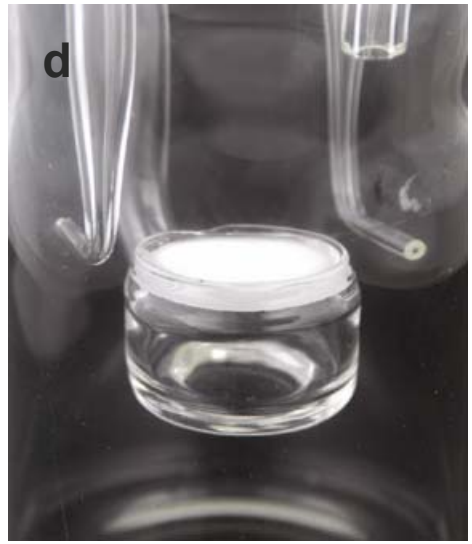


- *Applications*
  - *In vivo* toxin/infectious agent challenge
  - prophylaxis (i.e., inhalable vaccine)
  - Therapeutics (i.e., β^2 agonists)
  - Aerosol behavior and characterization
  - Test novel sampling technologies (flow cytometry)

Generation

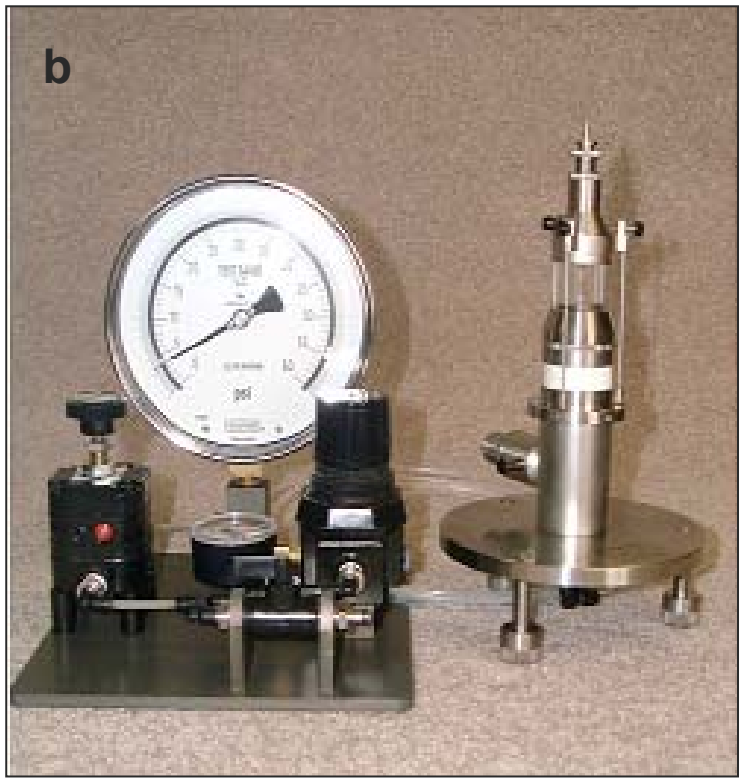
- Nebulizers
  - **Collison** (a)
  - BANG; one jet (b); three jet (c)
- Atomizers
  - two-fluid nozzle*
- Other
  - Fritted plate bubbler (d)





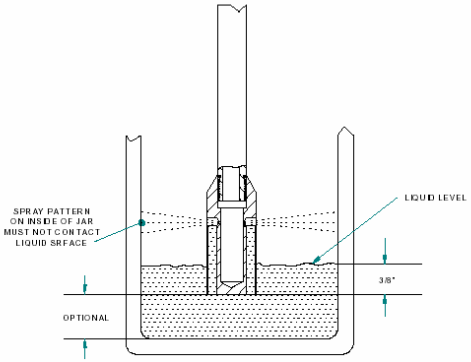
Generation (cont.)

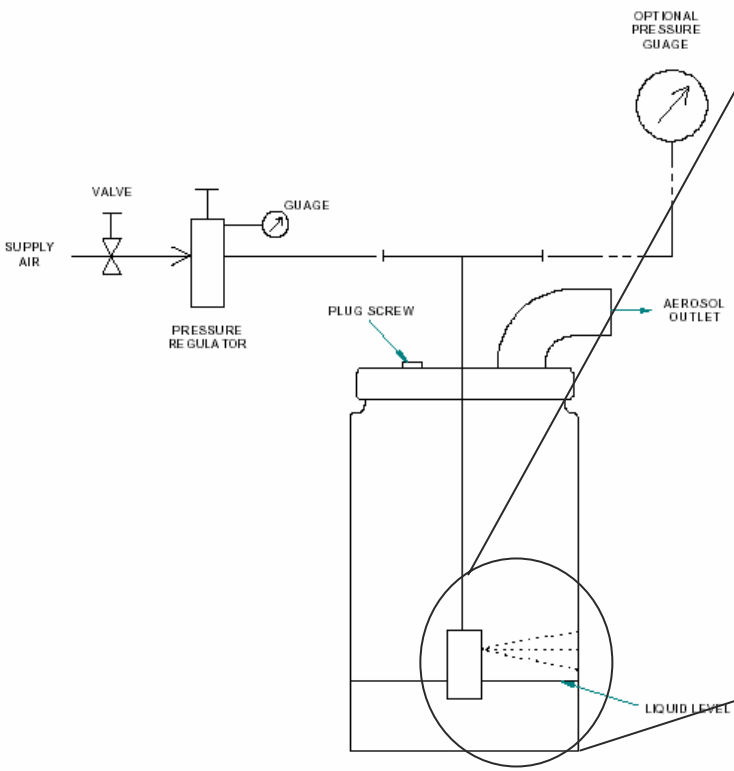
- Micro-pump generator
  - Ultrasonic (a)
- Monodisperse generators
  - Spinning top aerosol generator (STAG) (b)
  - Vibrating orifice aerosol generator (VOAG) (c)



atomizers and nebulizers

- Atomizers
  - interaction of a high-velocity air stream with a slow moving liquid flow
  - Liquid dispersed into gas-phase and converted to droplets
    - bulk fluid dispersion
    - droplet breakup
    - coalescence
    - external parameters that govern droplet size
- Nebulizers
  - modified atomizers
  - Functional differences
    - recycles fluid to be aerosolized
    - uses baffles/impaction sites to block primary spray from atomizer jets
    - preferential size distribution for inhalation into lung





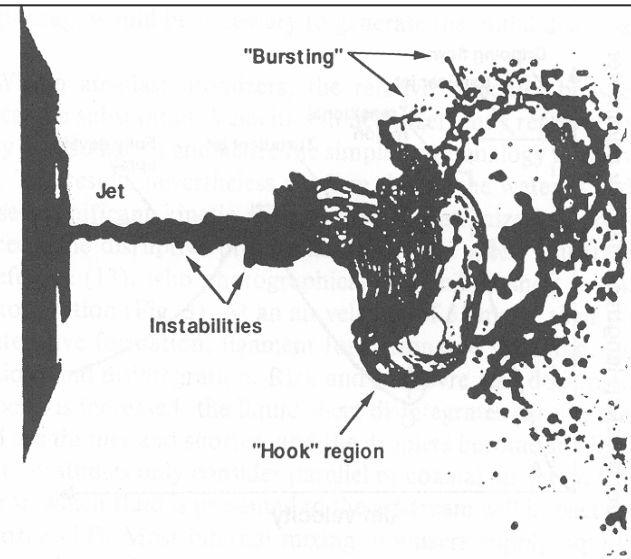


Figure 1 Depiction of the breakup of a jet emerging from a nozzle in quiescent air. Regions of instability are first generated, which is followed by extension of liquid elements and finally disruption. (Adapted from ref. 8.)

From BGIUSA.com

notes on the collison nebulizer

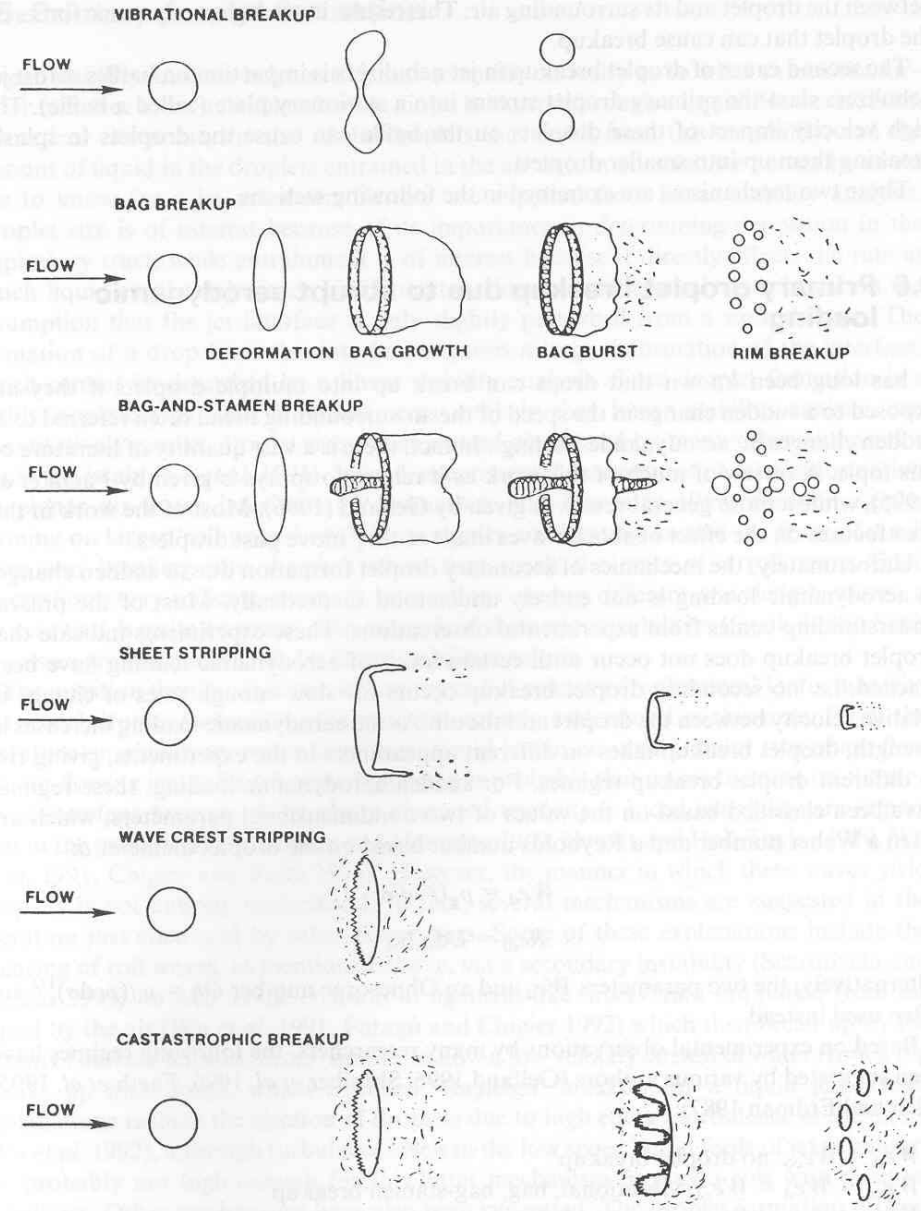
- Advantages
  - generates a small, minimally polydisperse aerosol
  - uncomplicated design; inexpensive
  - little training required relative to other dispersion devices
- Disadvantages
  - operational effects (concentration, temperature)
  - waste volume can exceed 50%
  - possible effects on sensitive proteins b/c of air-jet nebulization
    - generates a massive amount of surface area
      - 150 ml (air) /min at 20 psi (>50 ml/min/jet)
      - ≈1 mm jet; 1.4 cm - exit jet to wall
        - » estimate of air-liquid interface = 2,000 cm^2/min/jet (Niven, R.)

Performance Characteristics of the 3-jet Collison nebulizer

Pressure	MMAD	Liquid Generation Rate	air flow rate
(psig)	(μm)	(ml/hr)	(lpm)
20	1.0	4.5	6.0
40	0.9	8.25	10.0

Ref: **May K.R. (1973) The Collison Nebulizer. Description, Performance & Application *J. of Aerosol Science*, Vol. 4, #3, p. 235.**

Gussman, R.A. (1984) Note on the Particle Size Output of Collison Nebulizers, *Am. Ind. Hyg. Assoc. J (*45).



collison

Fig. 8.6 Schematic of secondary breakup mechanisms according to Pilch and Erdman (1987). Reprinted from Pilch and Erdman (1987) with permission.

From Niven, R.W., 1998. IN: Hickey, A.J., Inhalation Aerosols.

Table 2 Output Air Flow Rates and Aerosol Mass Outputs of the Nebulizers

	Air pressure (psig)								
	10			20			40		
	Air flow	Mass output		Air flow	Mass output		Air flow	Mass output	
Nebulizer	L/min	mL/min	μL/L	L/min	mL/min	μL/L	L/min	mL/min	μL/L
"Raindrop"	4.9	0.11	21.5	7.2	0.19	25.9	11.7	0.35	29.6
"Misty"	4.5	0.11	24.1	6.6	0.18	27.5	10.8	0.35	32.8
"Aerotech II"	4.9	0.09	19.0	7.0	0.14	19.7	11.4	0.20	17.4
"Cirrus"	4.8	0.10	21.0	6.9	0.20	43.0	11.2	0.37	33.1
Devilbiss #45 closed vent	6.9	0.15	21.5	10.2	0.31	30.0	16.8	0.46	27.5
Devilbiss #45[a] open vent	—	0.39	—	—	0.87	—	—	1.20	—
"Updraft"	2.7	0.05	19.1	4.1	0.17	41.7	6.8	0.32	46.3
"Whisperjet"[b]	4.2	0.10	22.5	5.9	0.20	33.1	9.4	0.39	40.8
"Acorn I"	5.2	0.13	25.7	7.4	0.27	36.4	11.9	0.47	39.9
"Acorn II"	3.6	0.06	15.9	5.2	0.15	23.7	8.4	0.42	50.4
Collison 1 jet	1.7	0.03	15.5	2.5	0.06	22.3	4.2	0.09	21.9
→ Collison 3 jet	4.9	0.08	16.5	7.3	0.15	20.7	12.0	0.38	31.7

[a]Output air flow rates of the DeVilbiss #45 nebulizer were not measured when the vent was open.
[b]Results are the mean values for six "Whisperjet" nebulizers.

From Niven, R.W., 1998. IN: Hickey, A.J., Inhalation Aerosols.

Table 3 Mechanical Efficiency of Nebulizers

Nebulizer	% Efficiency[a] Air pressure (psig) 5	10	20	30	40
Puritan Bennett "Raindrop"	0.20	0.37	0.60	0.92	1.34
Airlife "Misty"	0.13	0.21	0.27	0.26	0.33
Cadema "Aerotech II"	0.37	0.48	0.71	0.80	1.14
DHD "Cirrus"	0.20	0.37	1.16	1.19	1.70
Devilbiss #45 closed vent	1.09	1.19	1.74	1.69	1.64
Devilbiss #45 open vent	2.61	3.18	4.94	5.18	4.24
Hudson "Updraft"	0.10	0.18	0.53	0.80	1.01
Marquest "Whisperjet"[b]	0.19	0.33	0.62	0.93	1.03
Marquest "Acorn I"	0.29	0.46	0.68	0.83	1.02
Marquest "Acorn II"	0.16	0.32	0.70	1.00	1.74
Collision 1 jet	0.05	0.06	0.07	0.12	0.11
Collision 3 jet	0.08	0.10	0.14	0.15	0.15

[a]The percent mechanical efficiency as defined by the percent ratio of the mean aerosol output to the mean aspiration rate.
[b]The mean percent mechanical efficiency obtained for six "Whisperjet" nebulizers.

From Niven, R.W., 1998. IN: Hickey, A.J., Inhalation Aerosols.