CPP ~ Wind Engineering Consultants

Specifying Exhaust Systems to Minimize Energy Cost While Maintaining Acceptable Air Quality

Laboratories for the 21st Century

October 6-9, Raleigh/Durham, NC

by

Ron Petersen, Ph.D.

and

John Carter

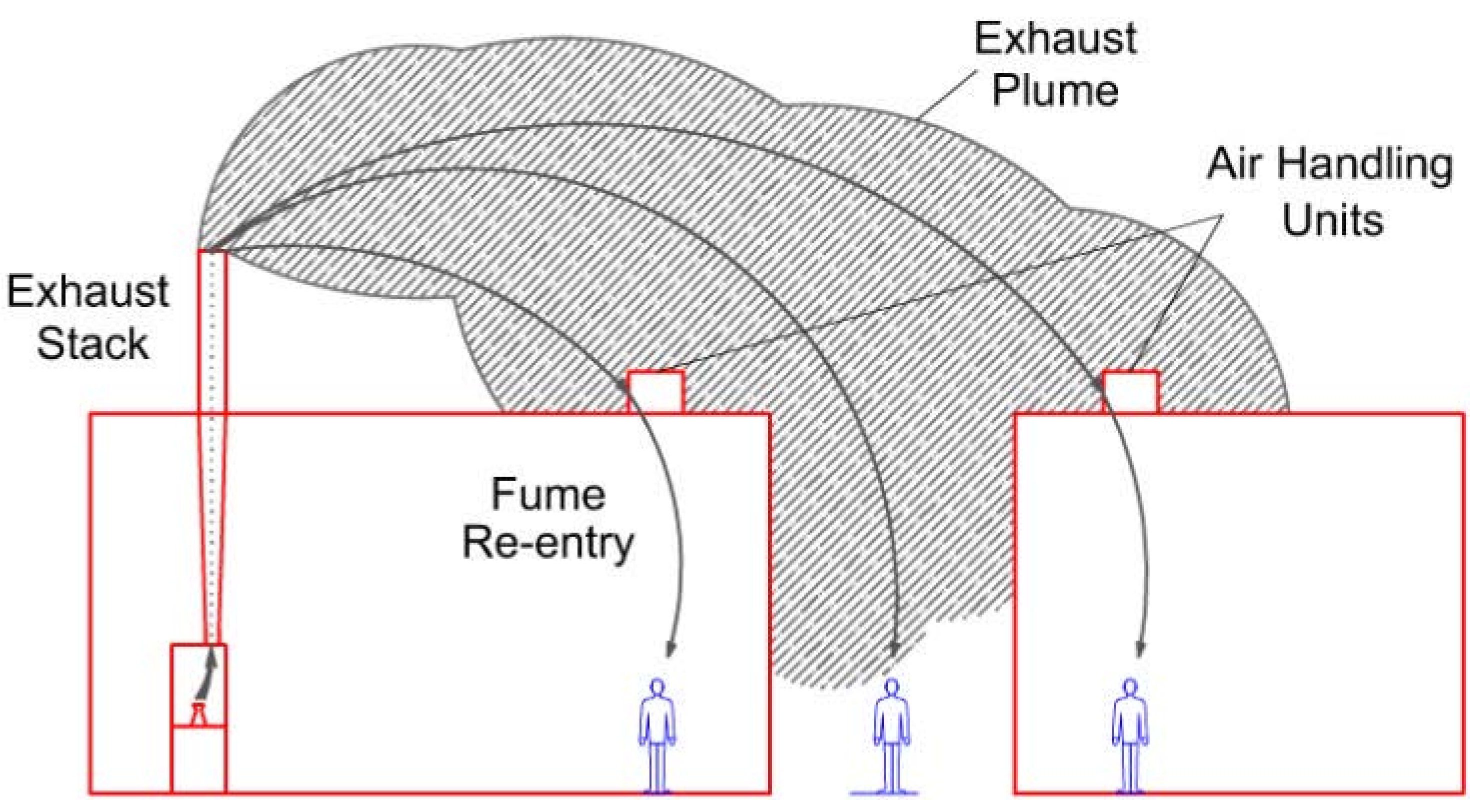
Cermak Peterka Petersen, Inc.

rpetersen@cppwind.com

OUTLINE

- Reentry of Pollutants
- Specification of Acceptable Exhaust Design
- Relating Energy Cost to Exhaust Design
- Examples from Recent Projects

Acceptable Air Quality & Reentry of Pollutants



Specifying Exhaust and Intake Systems

by

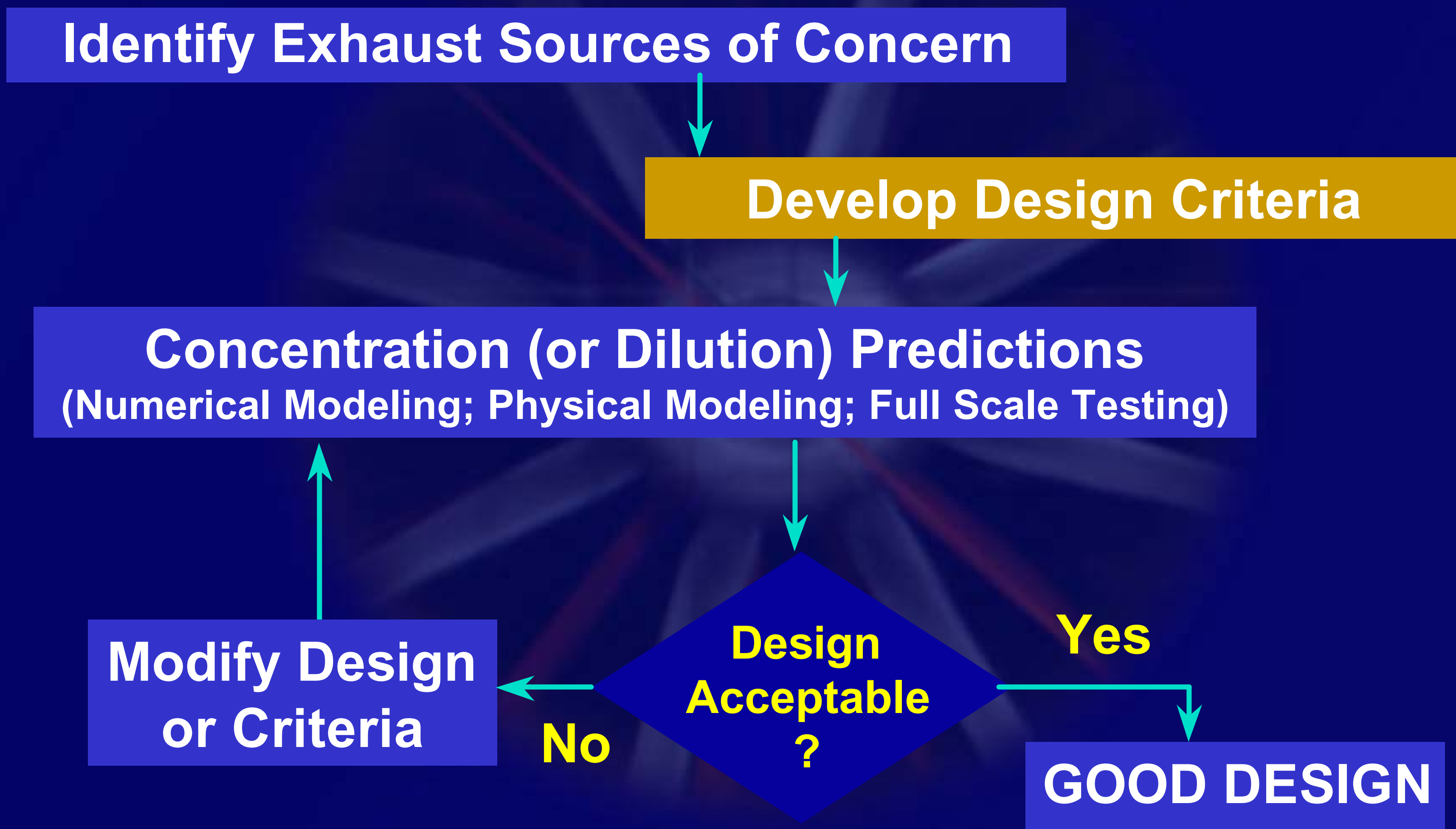
Petersen, Cochran and Carter

ASHRAE Journal, August 2002

Plume impact on taller downwind building

Plume impacting taller upwind building

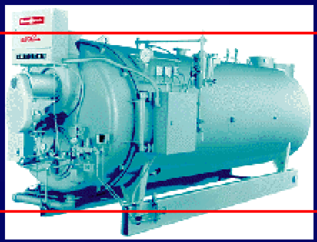
Specifying an Acceptable Design



Identify Sources of Concern

Chemical Fume Hood

Boiler

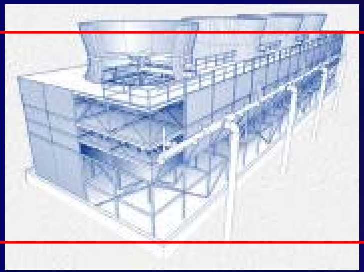


Radioisotope

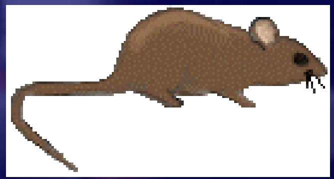
Biosafety Cabinet & Isolation Room

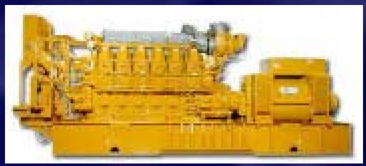
Traffic

Cooling Tower



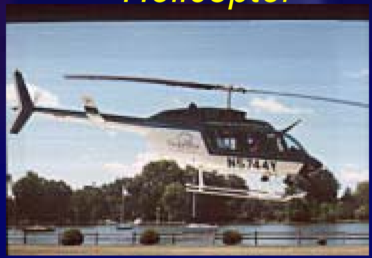
Animal Room





Emergency Generator

Helicopter

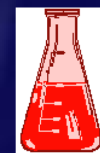


Diesel Vehicles

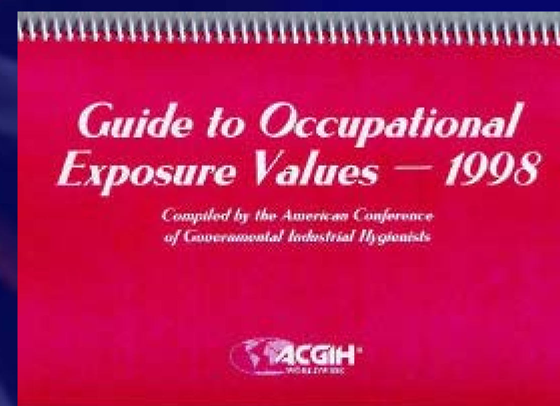
Also:

- Kitchen Hood Exhaust
- Ethylene Oxide (EtO)

Concentration Design Criteria (continued)



- Health Limits (**C_{health}**)
  - Lowest of ACGIH, OSHA and NIOSH
    - STELs (15 Minute Averaging Time)
    - 8 hr TWA multiplied by 3
  - Safety Factor of 5 (ANSI/AIHA Z9.5 – Changing)



- Odor Thresholds (**C_{odor}**)
  - ACGIH; various research

Concentration Design Criteria (continued)

- ***Mass emission rates (m)***
  - *Chemical hood emissions*
    - *EPA equation for accidental spill*

$$m ? \ 6.94x10^{?4} (1 ? \ 0.0043[T ? \ 273.15]^2) U_r^{0.75} A \, M \frac{V_p}{V_{pk}}$$

- *1 minute lecture bottle evacuation*

General Design Criteria

- ASHRAE Lab Handbook Chapter 13
  - Use 5000:1 for 1000 cfm flow
  - Use 400 mg/m^3 per g/s
- ASHRAE 110 Fume Hood Testing
  - Use 3000:1 for 1000 cfm flow
  - Use 700 mg/m^3 per g/s
  - AM.05 Rating.

Concentration Predictions

- **Analytical – may add energy cost**
- **Computational Fluid Dynamics (CFD) – not ready for routine applications**
- **Wind Tunnel Modeling (WT) – most accurate, best for optimizing design**
- **See previous presentations @** *www.epa.gov/labs21century*

Wind Tunnel Modeling -- Like a Field Study, Controlled Meteorology, Design Changes

Wind Tunnel Concentration Measurements at Air Intake

Relating Energy Costs to Exhaust Design

Exhaust Design Factors Affecting Energy Costs

- Air Intake Locations
- Building Design and Existing Environment
- Chemical Utilization
- Volume Flow/Exit Velocity
- Local Meteorology

Exhaust Evaluation Approach

Air quality acceptability question:

LEEDS Credit 9.1 -- Meet all standards and generally accepted guidelines for outdoor protection of workers and general public from airborne chemical, radioactive and biological hazards. Use mathematical modeling, physical modeling and/or post construction testing and certification to prove compliance.

$$C_{max} \leq C_{health/odor}$$

Factors Affecting Concentration

$$C ? \frac{m}{\{? \; ?_y ?_z U_s\}} \exp[? \frac{H^2}{2 ?_z^2}] x 10^6$$

$$\frac{1}{\{? \; ?_y ?_z U_s\}}$$

Site and Design Effects Term

$$m ? \exp[? \frac{H^2}{2 ?_z^2}]$$

Energy Term

Plume Rise Predictions – Main Energy Term

$$H \sim h_s + A\,[CFM \times FPM]^{1/3}$$

~ *Fan Horsepower*

Entrained Air Stacks on Lab Roof

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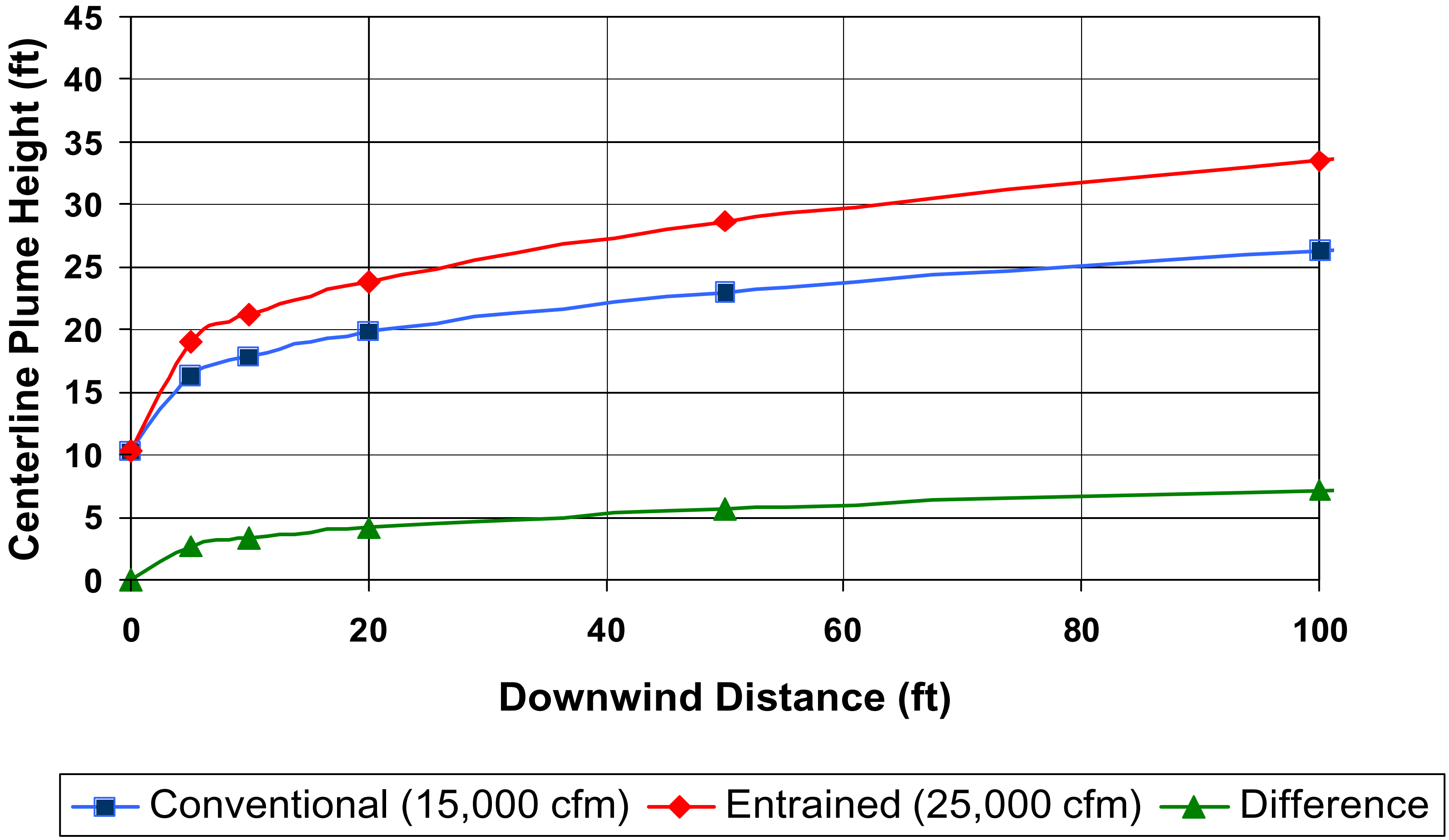
Conventional vs. Entrained Air – 20 mph



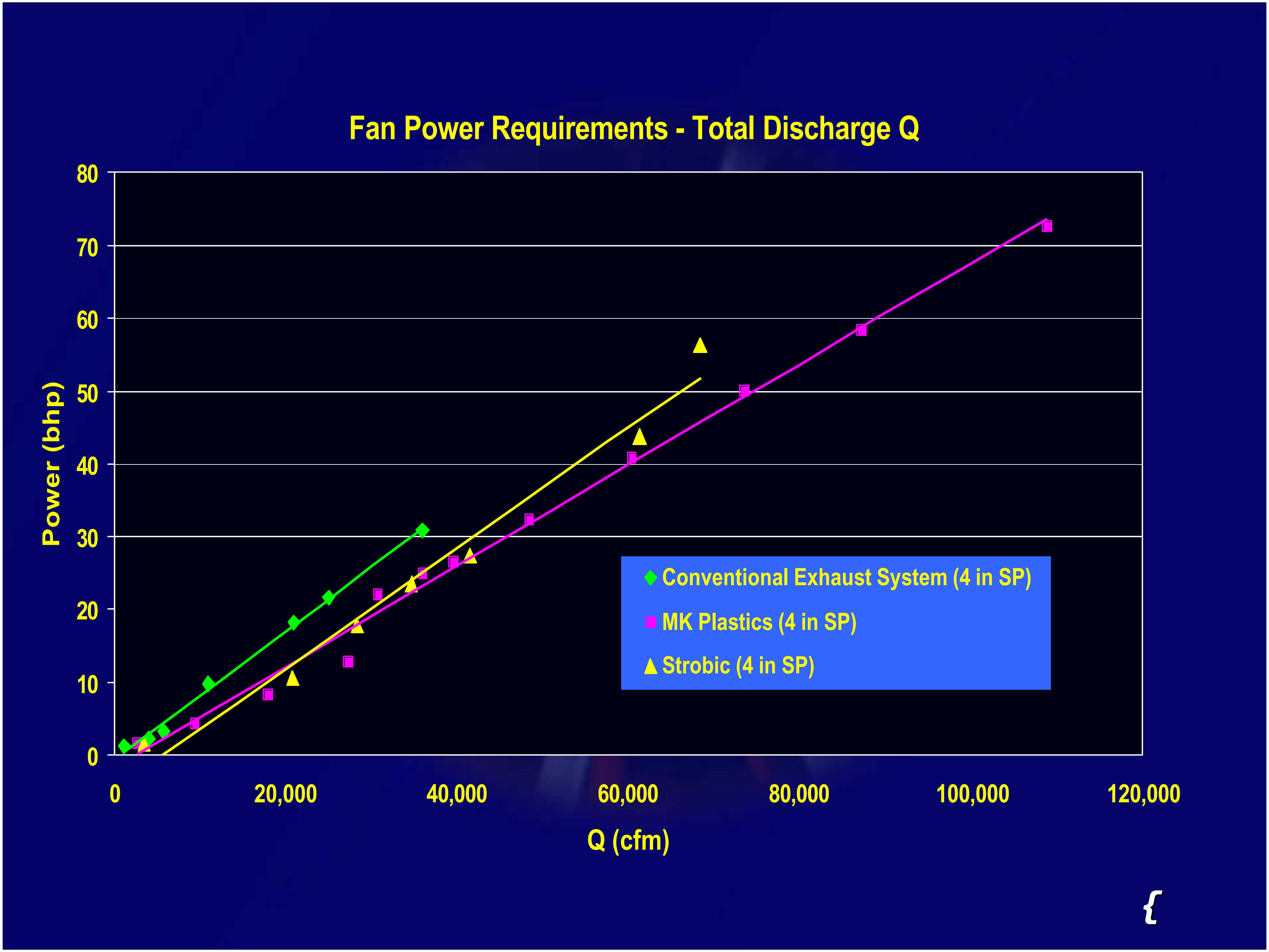
Examples

- CDC Building 110
- Pomona College
- Commercial Medical Research Lab

Stack Design and Results Information

Source Description	Stack ID	Stack Height hs (ft)	Volume Flow Rate Q (cfm)	Exit Velocity Ve (fpm)	Motor Size[1] (bhp)	Annual Energy Cost ($)	Design Criterion HL/m (µg/m³)/(g/s)	Max Measured C/m (µg/m³)/(g/s)
CDC Building 110 - Laboratory								
Initial Specifications	CDC-Lab (EAE)	21.0	60,000	3,056	52.3	$20,340	230	81
Recommended Specifications	CDC-Lab (CE)	21.0	30,000	1,528	25.9	$10,054	230	162
CDC Building 110 - Emergency Room								
Recommended Specifications (Conventional)		6.4	5,800	6,292				
Recommended Specifications (Axijet 1500)	CDC-ER (EAE)	6.4	8,210	3,898	6.9	$2,683	230	236
Equivalent Recommended Specifications (Conventional)	CDC-ER (CE)	6.4	10,606	3,000	8.8	$3,404	230	259
Pomona College NBB - Laboratory								
Initial Specification (Axijet 3650)	PC-Lab (EAE)	12.9	24,000	3,876	15.6	$6,083	400	Not Tested
Recommended Specifications (Conventional)	PC-Lab (CE)	10.0	15,000	3,000	12.6	$4,910	400	339
Commercial Medical Research - Laboratory								
Entrained Air Exhaust (Axijet 6000)	CMR-Lab (EAE)	22.8	64,000	4,420	41.4	$16,093	230	230
Conventional Exhaust	CMR-Lab (CE)	30.0	40,000	3,000	34.7	$13,482	230	212
Commercial Medical Research - Vivarium								
Entrained Air Exhaust (Axijet 6600)	CMR-Viv (EAE)	22.5	96,000	6,630	67.3	$26,158	353	92
Conventional Exhaust	CMR-Viv (CE)	17.5	60,000	3,000	52.3	$20,340	353	209
Commercial Medical Research - Biosafety Cabinet								
Entrained Air Exhaust (Axijet 1825)	CMR-BSC (EAE)	25.0	9,200	4,819	4.2	$1,649	400	440
Conventional Exhaust	CMR-BSC (CE)	32.0	4,000	3,000	2.9	$1,139	400	400
Commercial Medical Research - Radioisotope								
Entrained Air Exhaust (Axijet 1825)	CMR-RIE (EAE)	7.0	9,200	4,819	2.2	$863	4,637	2,892
Conventional Exhaust	CMR-RIE (CE)	17.0	2,000	3,000	1.2	$453	4,637	3,182

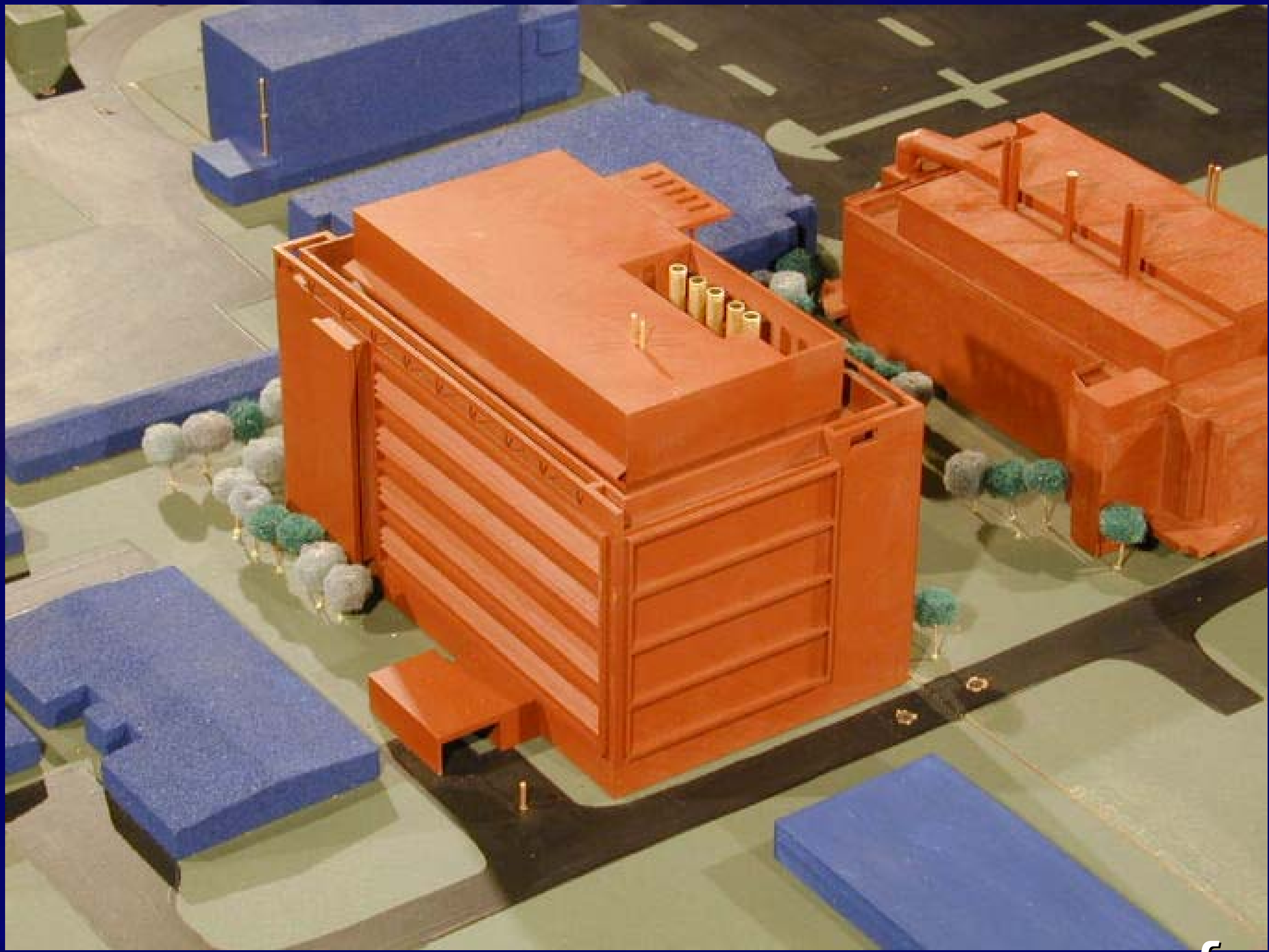
1) Motor size for conventional system based on 4 in static pressure.


Fan Power Requirements - Total Discharge Q
Power (bhp)
0
10
20
30
40
50
60
70
80
0
20,000
40,000
60,000
80,000
100,000
120,000
Q (cfm)
Conventional Exhaust System (4 in SP)
MK Plastics (4 in SP)
Strobic (4 in SP)

Inputs to Calculations

- kW - hr = 0.7457 x bhp – hr
- Unit cost = $0.06 per kW-hr

CDC Building 110



CDC Building 110

Laboratory Exhaust Stacks

Parameter	Entrained Air	Conventional
Stack Height (ft)	21	21
Volume Flow (cfm)	60,000	30,000
Exit Velocity (fpm)	3,056	1,528
Fan Size (HP)	52	26
Annual Energy Cost	$20,340	$10,054
Design Criterion, HL/m	230	230
Max Measured C/m	81	162

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CDC Building 110

Emergency Room

Parameter	Entrained Air	Conventional
Stack Height (ft)	6.4	6.4
Volume Flow (cfm)	8,210	10,606
Exit Velocity (fpm)	3,898	3,000
Fan Size (HP)	6.9	8.8
Annual Energy Cost	$2,683	$3,404
Design Criterion, HL/m	230	230
Max Measured C/m	236	259

CDC Building 110 – Lab Exhaust

Pomona Model

Pomona Research Lab

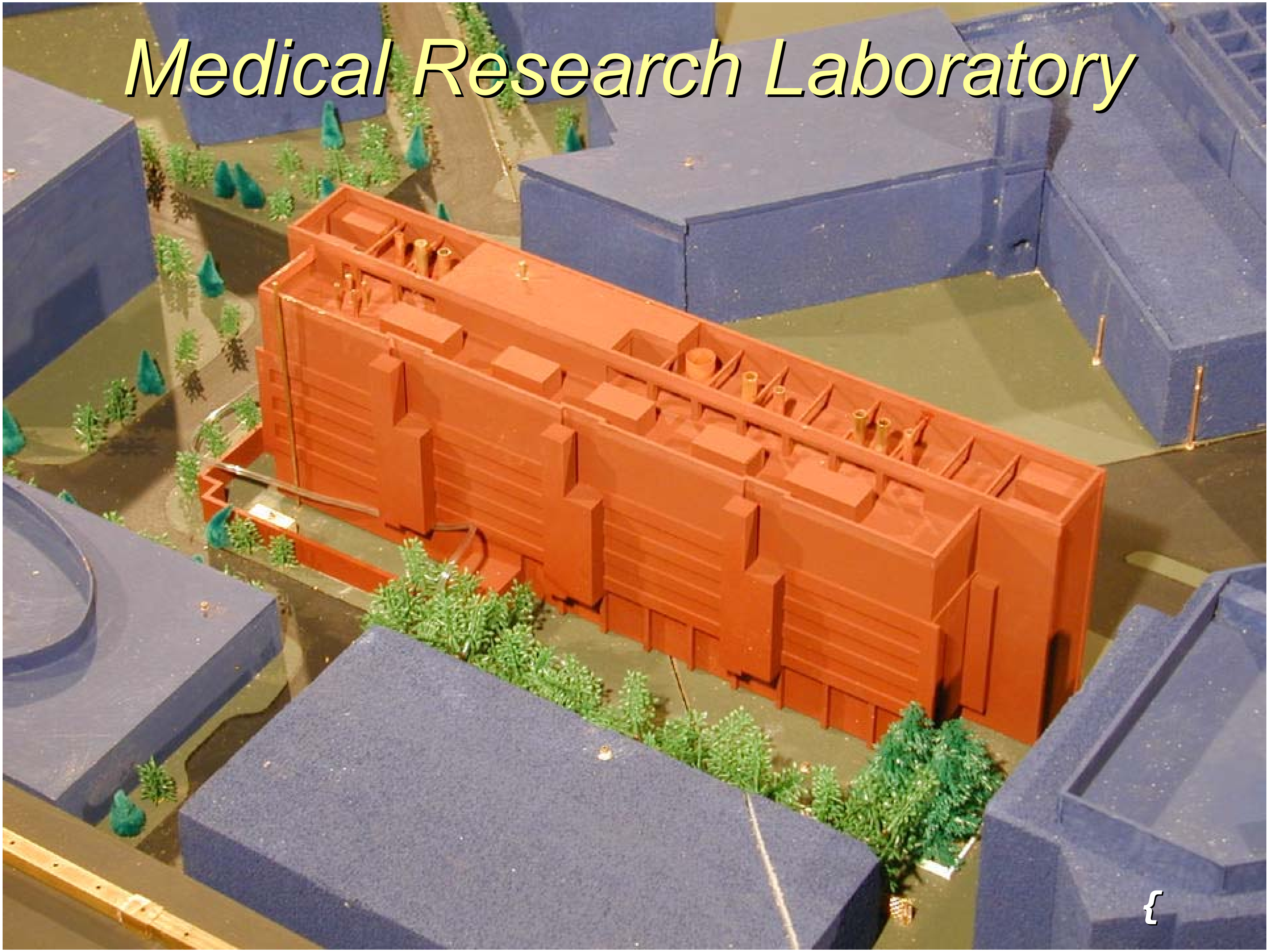
Pomona College

Laboratory Exhaust Stacks

Parameter	Entrained Air	Conventional
Stack Height (ft)	12.9	10
Volume Flow (cfm)	24,000	15,000
Exit Velocity (fpm)	3,876	3,000
Fan Size (HP)	15.6	12.6
Annual Energy Cost	$6,083	$4,910
Design Criterion, HL/m	400	400
Max Measured C/m	<339	339

Pomona Lab Exhaust

Medical Research Laboratory



Medical Research Laboratory

Laboratory

Parameter	Entrained Air	Conventional
Stack Height (ft)	22.8	30
Volume Flow (cfm)	64,000	40,000
Exit Velocity (fpm)	4,420	3,000
Fan Size (HP)	41.4	34.7
Annual Energy Cost	$16,093	$13,482
Design Criterion, HL/m	230	230
Max Measured C/m	230	212

Medical Research Laboratory

Vivarium

Parameter	Entrained Air	Conventional
Stack Height (ft)	22.5	17.5
Volume Flow (cfm)	96,000	60,000
Exit Velocity (fpm)	6,630	3,000
Fan Size (HP)	67.3	52.3
Annual Energy Cost	$26,158	$20,340
Design Criterion, HL/m	353	353
Max Measured C/m	92	209

Summary – Specifying Exhausts to Minimize Energy Use

- Use guidelines
- Caution using vendor effective height specification – evaluate like regular exhaust
- Recommended approach
  - Design criteria development
  - Concentration predictions using accurate method
  - Design to meet criteria
- Designs that avoid air quality problems and minimize energy costs