Fans and air cleaners

Introduction

- The ventilation system depends on the fan to work
- Many variables affecting fan performance
- Selection should consider:
  - performance characteristics of the fan
  - temperature, humidity
  - contaminants corrosiveness, abrasiveness, stickiness, and flammability
  - fan installation and noise control.

- Definition and Description
- Fan moves air at pressures low enough that compression can be ignored.
- The most common fan are axial and centrifugal fans.

Fan Selection

- Fan can produce a wide range of airflows °˙consult fan curve
- Cost of operation °˙efficiency °˙best in the middle of the fan curve
- Reliability °˙Q varies less with SP for some fans than others
- Stability °˙at higher Ps fans may become unstable, vibrate, Q may oscillate
- Abrasive, sticky or stringy air contaminants. °˙radial blade fan
  - May have replaceable wear plates to extend life
- Corrosive atmospheres °˙special alloys, coatings or materials required
- High temperature airstreams °˙materials' strength reduced at high T

Flammable and explosive atmospheres

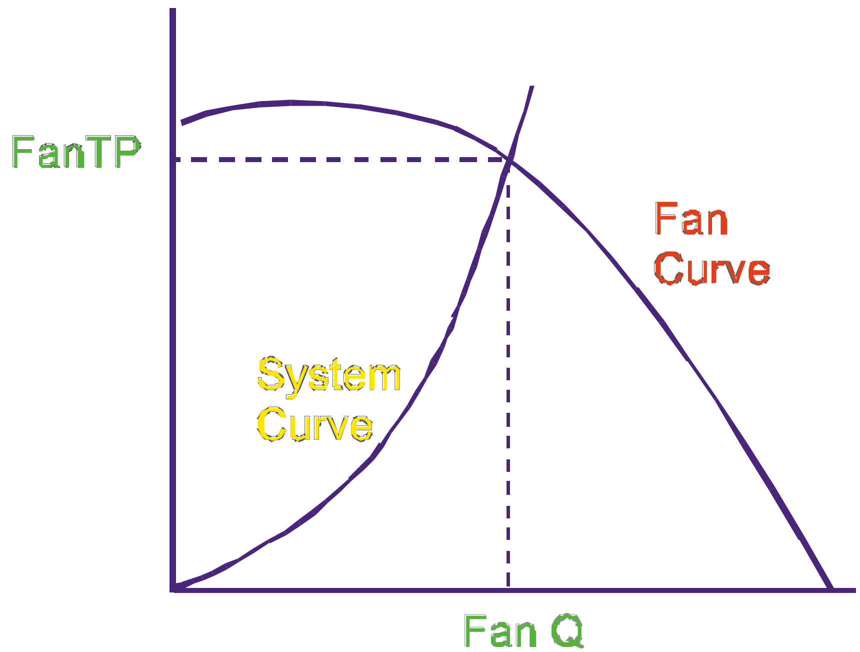
- Air Movement and Control Assoc.
- A.M.C.A. standard 401-66 for fans used with flammable materials
  - non-ferrous, non-sparking construction
  - explosion proof motors, rating A, B, or C with polyvinyl chloride plastic impeller
  - All parts of the air moving device in contact with the air or gas being handled shall be made of non-ferrous material
  - The air moving device shall have an entirely non-ferrous wheel or impeller and non-ferrous ring about the opening through which the shaft passes.
  - The air moving device shall be so constructed that a shift of the wheel or impeller or shaft will not permit two ferrous parts of the air moving device to rub or strike.
  - Notes: (1) Bearings shall not be placed in the air or gas stream.
    (2) The user shall electrically ground all air moving device parts.
- You should consult with the manufacturer before purchasing the fan for use in explosive atmospheres

Fan P_T and Fan P_s

- Fan imparts energy to the air in two forms:
  - kinetic energy °˙ velocity pressure °˙air movement
  - potential energy °˙static pressure °˙overcomes losses
- Fan total pressure (FanTP)
  - differential total pressure across the fan
- $FanP_T = P_{s,outlet} + P_{v,outlet} - P_{s,inlet} - P_{v,inlet}$
- Fan static pressure ($FanP_s$)
- Most fan vendors use $FanP_s$ to rate
- $FanP_s = FanP_T - P_{v,outlet}$

Fan/System Curves

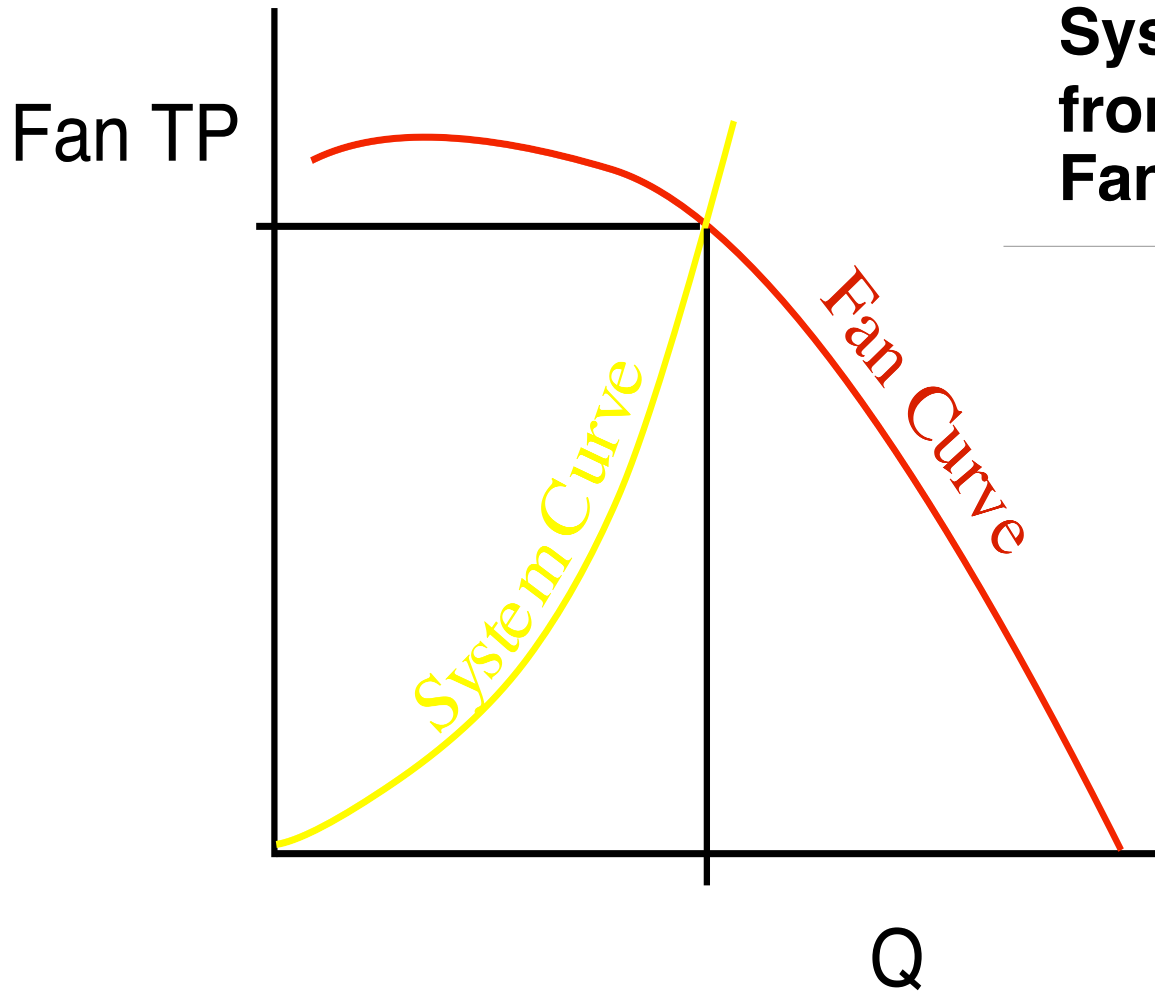
Fan does not generate a given airflow or a given pressure, but a combination of the two determined by the operating characteristics of the fan and by the resistance to flow of the system to which it is connected.



Factors affecting fan performance

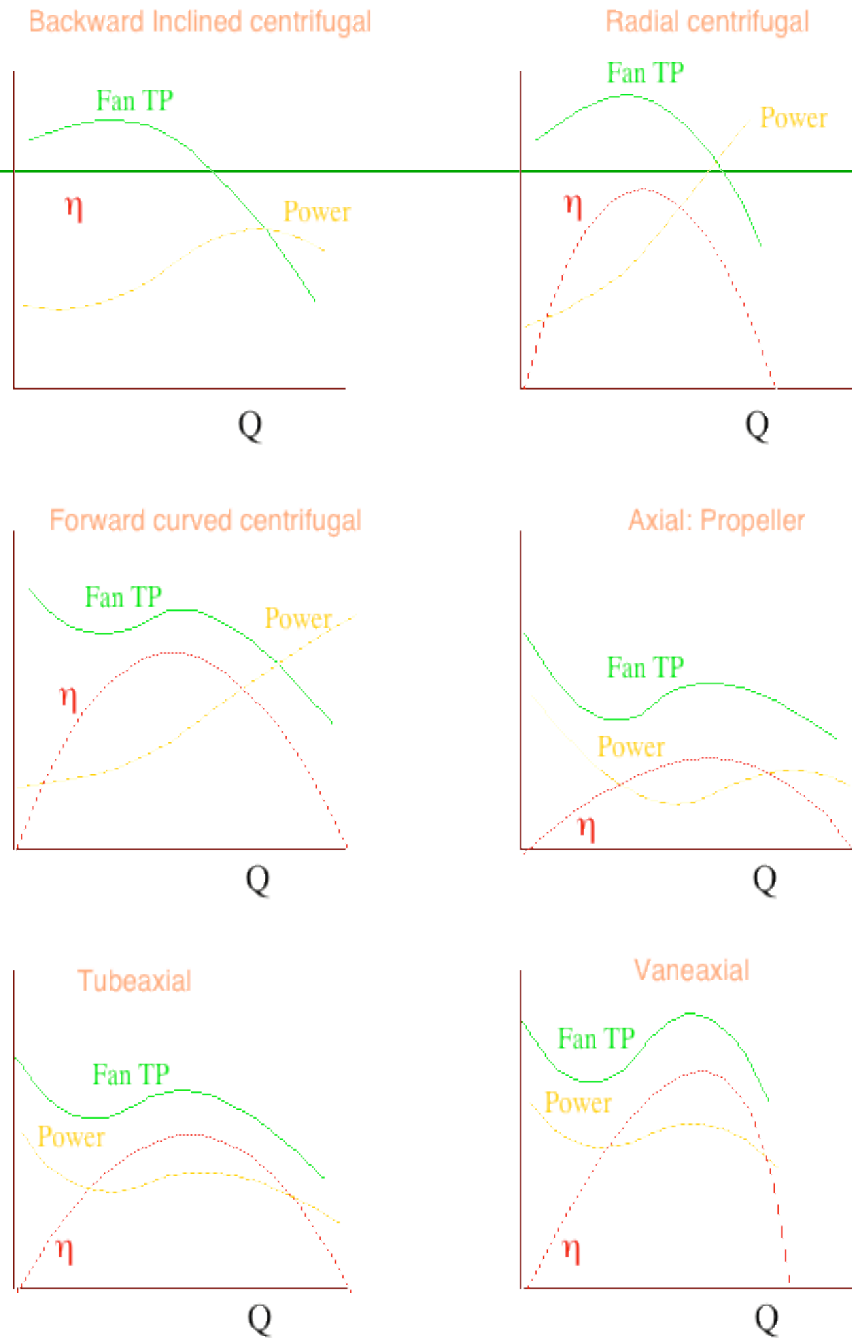
- Factors affecting fan performance
- Trade-off of Q versus fan pressure (system resistance effects)
- Air density (r)
- Fan impeller rotation rate (w)
- The wheel diameter of the fan
- Shape of the inlet cone, the blade type (forward curve, backward curve, radial) and other construction details
- Pitch of the impeller blades for variable pitch blades
- Maintenance and cleanliness of the fan: less flow if the blades are pitted, caked with grime, inlet cone misaligned.
- Inlet conditions: non-uniform distribution of air to the fan wheel, the fan will produce much less airflow
- Inlet vanes: vanes located just upstream of the fan can be slanted such that they create a vortex just at the fan inlet.

Fan Curve Vs System Curve



System Curve:
from TP = F VP
FanTP ∝ Q^2

Fan Curves for Axial Flow and Centrigual Fans



Fan Laws

$$Q \;\alpha\; \omega$$

$$\text{Fan TP} \;\alpha\; \omega^2$$

$$\text{Power}_{motor} \;\alpha\; \omega^3$$

$$\text{Power}_{motor} = \frac{Q\,\text{Fan TP}}{\eta_{drive}\eta_{fan}C_{units}}$$

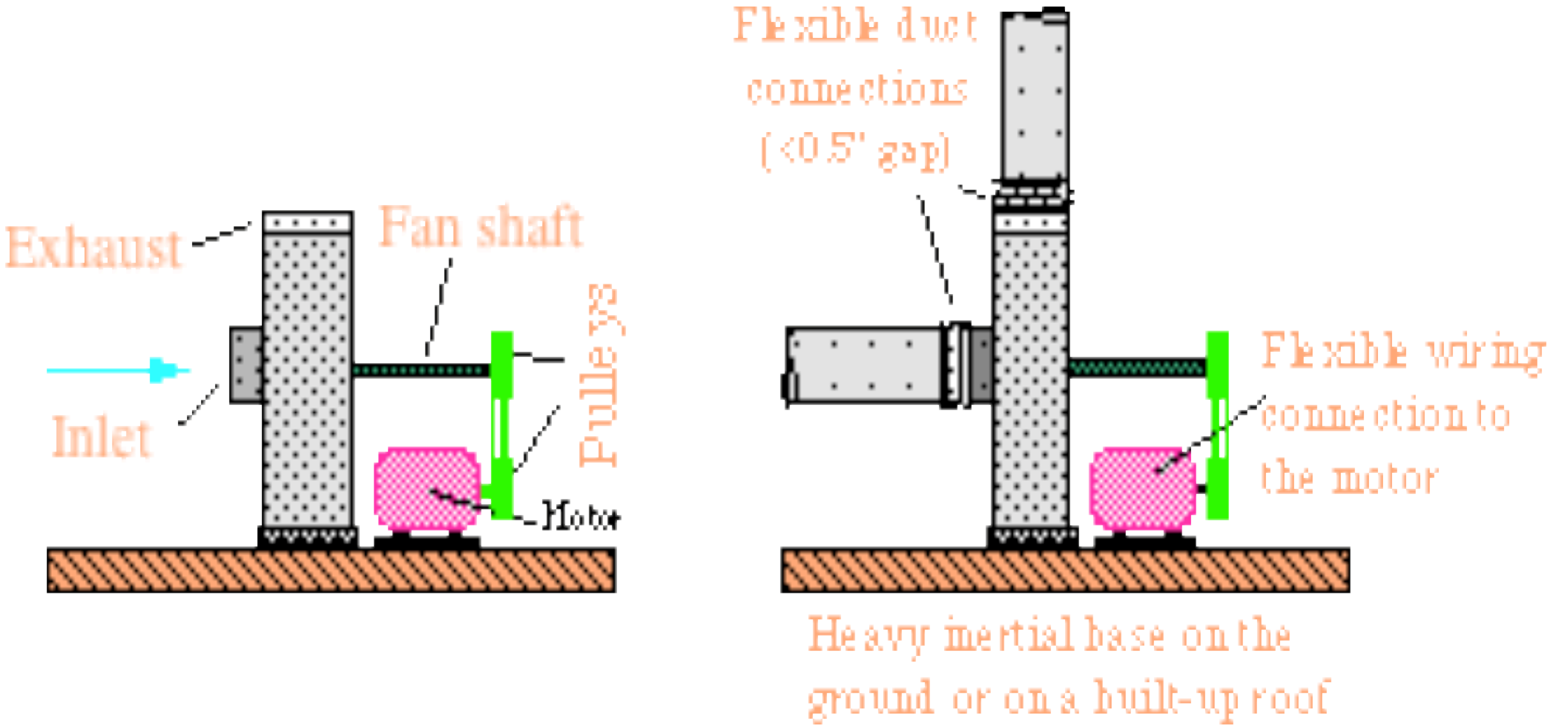
Finding lookup values for fan tables

$$\text{Table Q} = \text{actual Q}$$

$$\text{Table pressure} = \frac{\text{fan pressure}}{\text{df}}$$

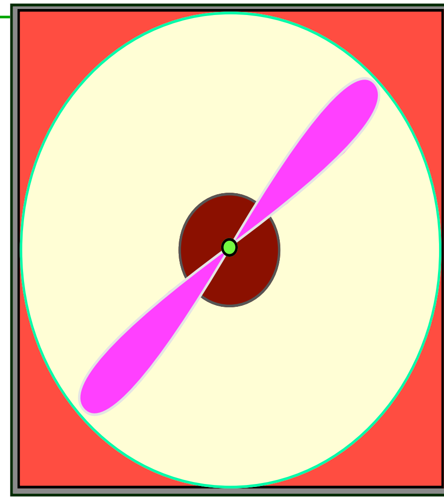
$$\text{actual brake power} = \text{Table value} * \text{df}$$

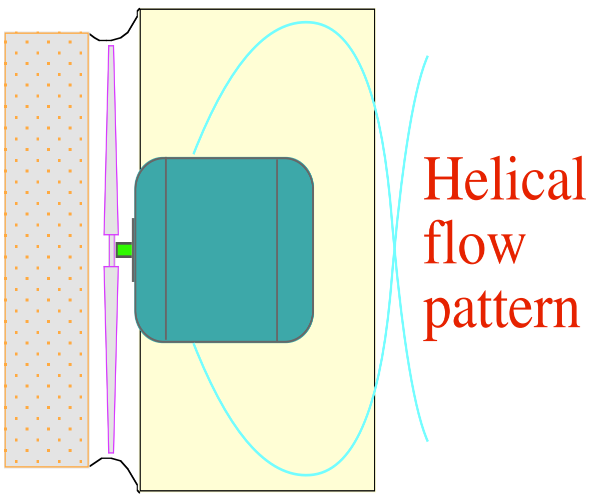
Centrifugal Fan Installation



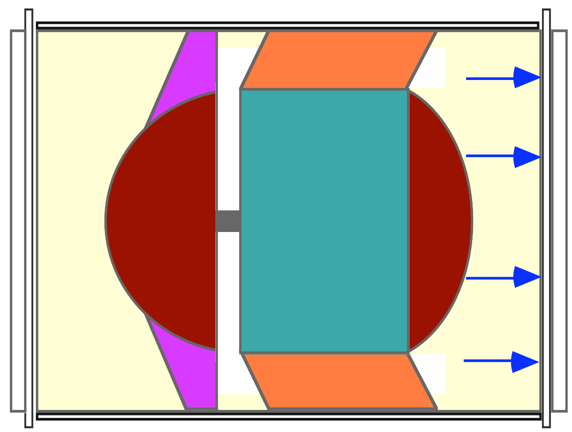
Axial Flow Fans

Propeller



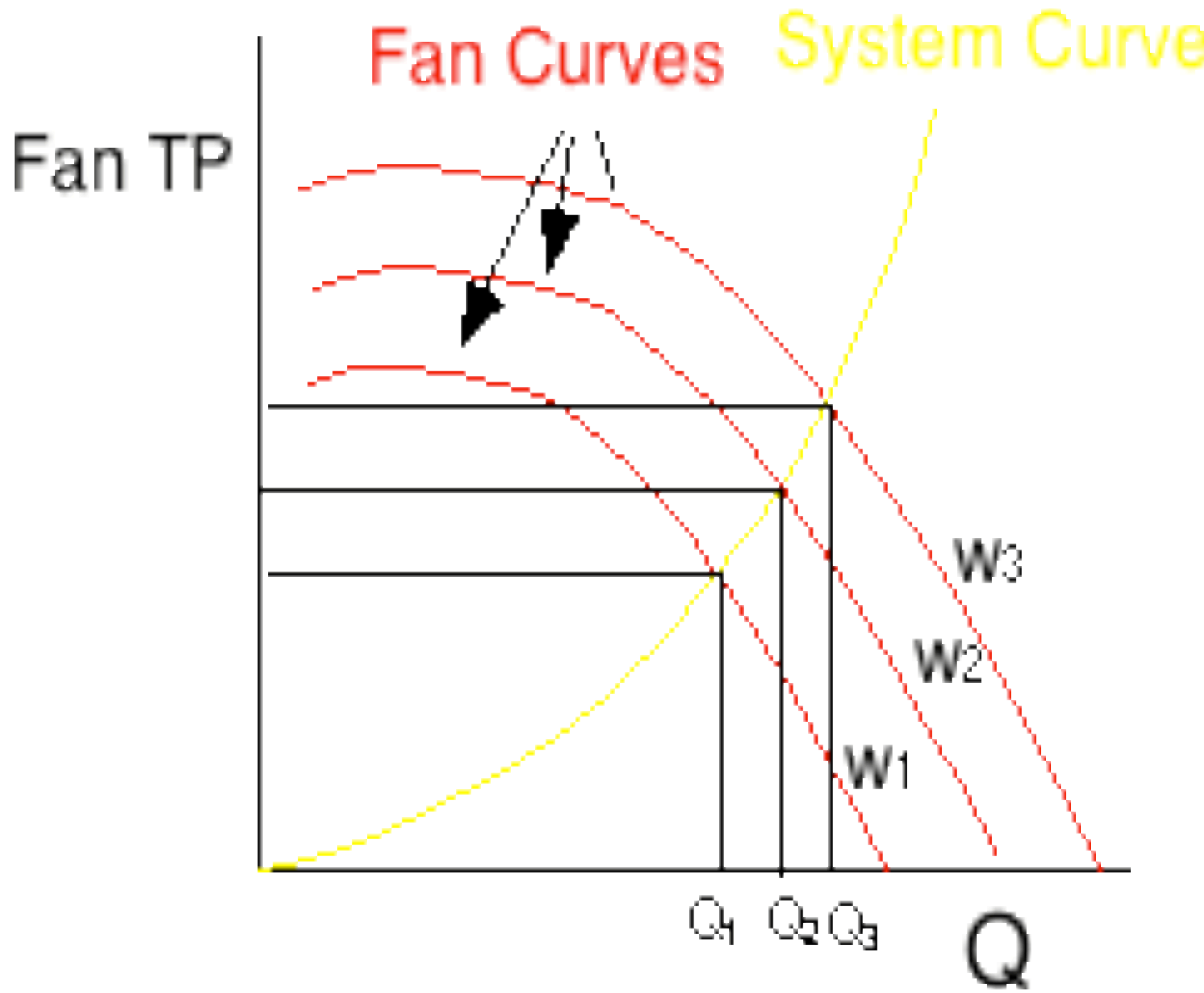


Tubeaxial

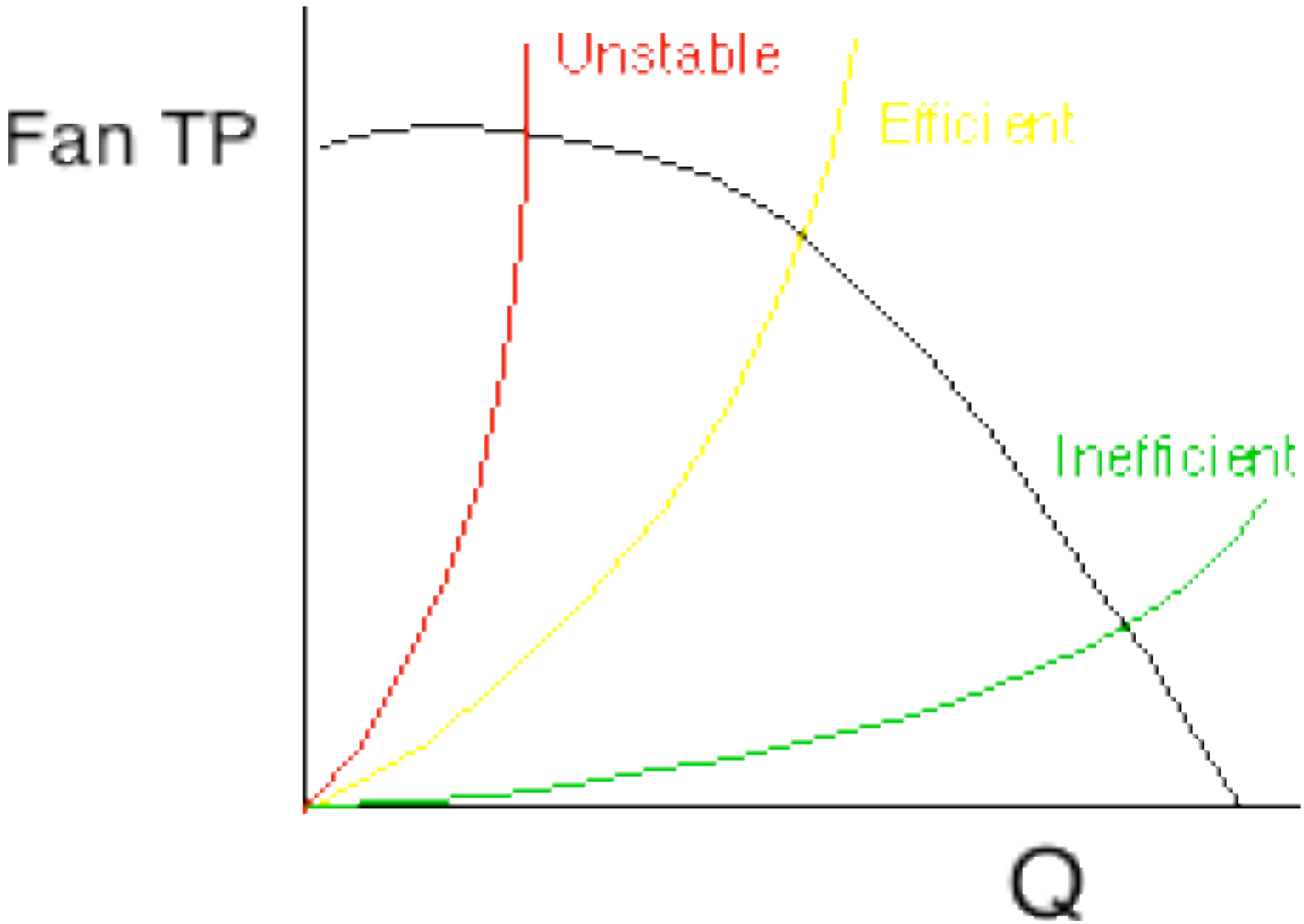


Vane-axial

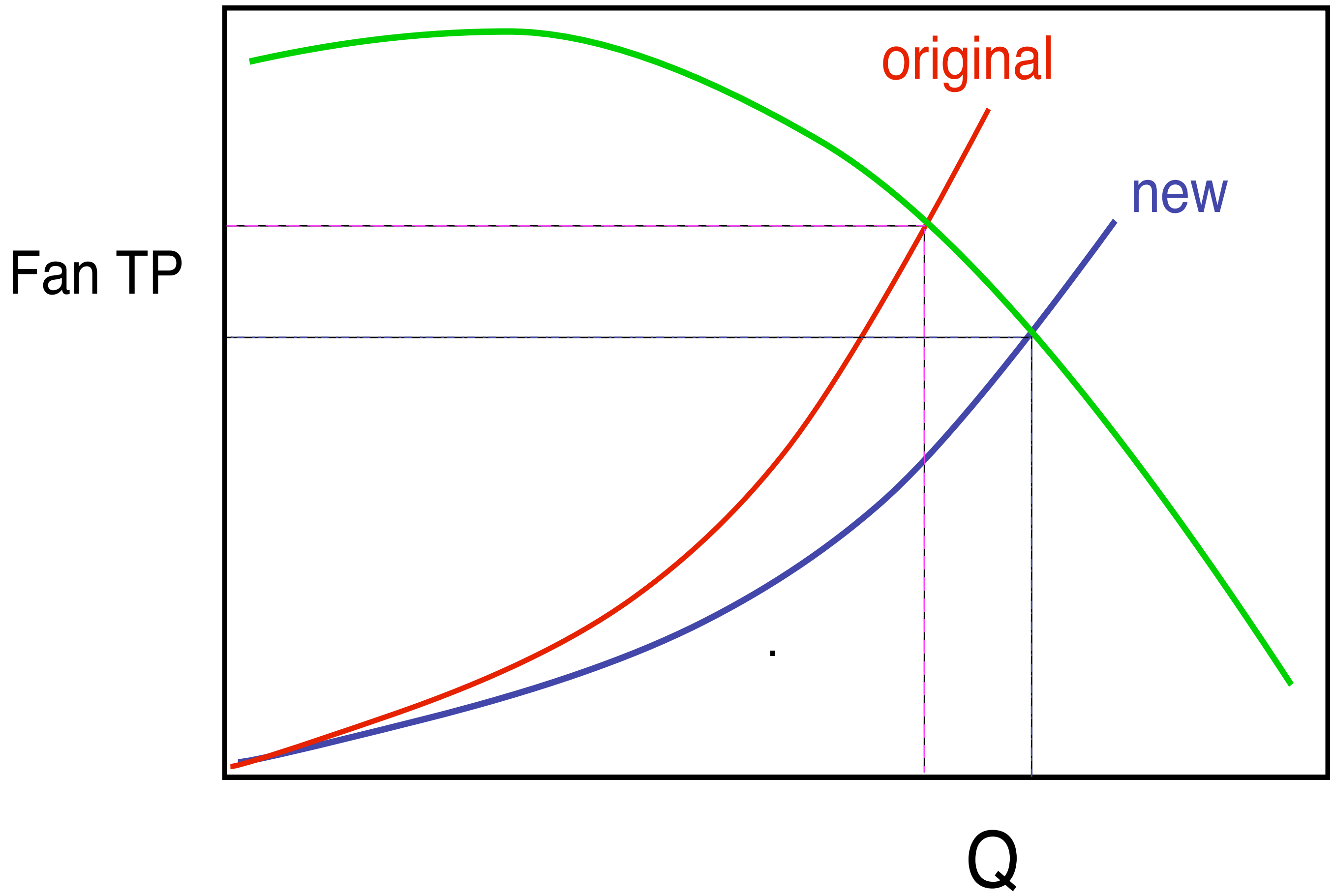
Effects of Changing Fan Speed



Fan Must Match the System's Requirements

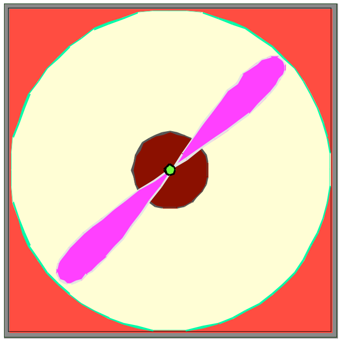


Changing (or incorrectly estimating) system/ fan

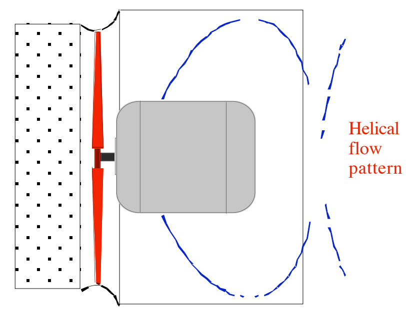


Axial flow fans

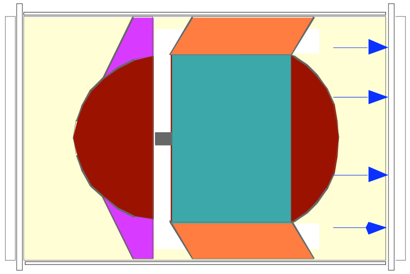
- Air flows along axis of propeller shaft
- Most common example is the ubiquitous man-cooling fan, which expects works only if there is "free flow".
- Walls or ceilings fans designed to produce large volumes of air against very small static pressures (<0.1").



- Tube-axial fan
- Designed for use in ductwork.
- Inexpensive; poor-quality construction
- Can produce airflow against as less than 0.5" fan static pressure
- Ability to produce static pressure limited by swirl.

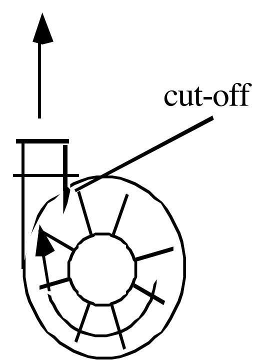


- Vane-axial
- Vanes on vane-axial fans prevent swirling, allowing vane-axial fans to produce large volumes against significant pressures (e.g., as much as 10"w.g.).
- Use for large airflows against very low pressures.
- Can produce pressures of 10" but efficiency falls at higher pressures.
- At less 3" w.g. efficiency < backward inclined, but lower initial costs may make them economically competitive with centrifugal fans for high volumes of air (>1000 cfm).

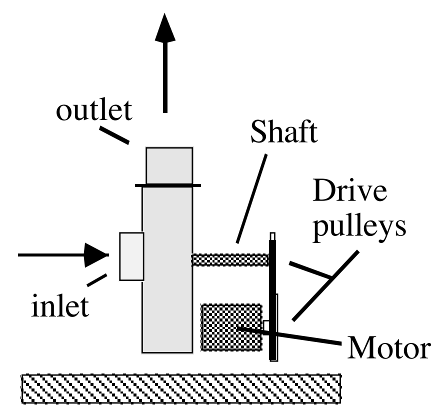


Centrifugal Fans

- Air enters "centrifugal" fans axially and is then pushed centrifugally by the blades until they shovel the air out.
- 3 main types of centrifugal fans: forward curved, radial blade, and backwardly inclined.



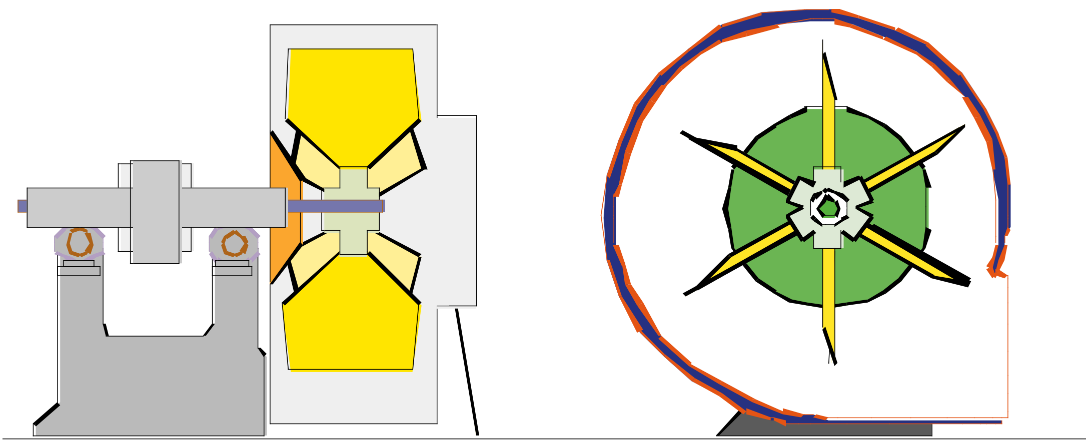
Schematic of radial blade fan



Fan with Motor and Drive

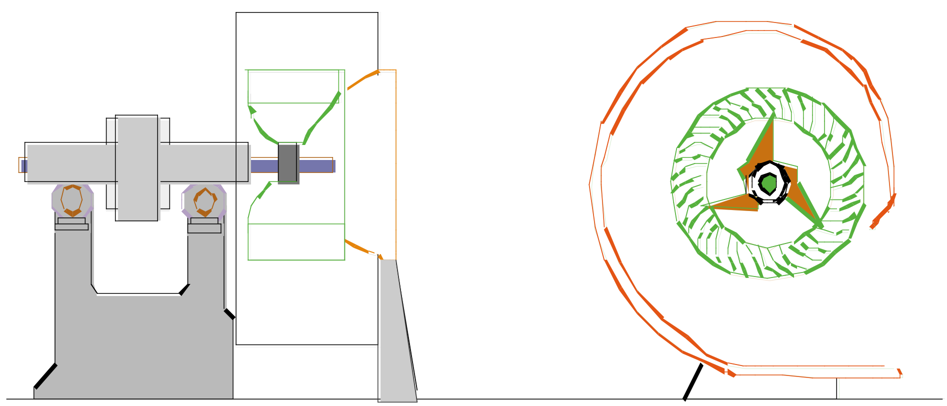
Radial blade fans

- handles dirty air well, but last longer with clean air
- less efficient than backward inclined blade fans and noisier



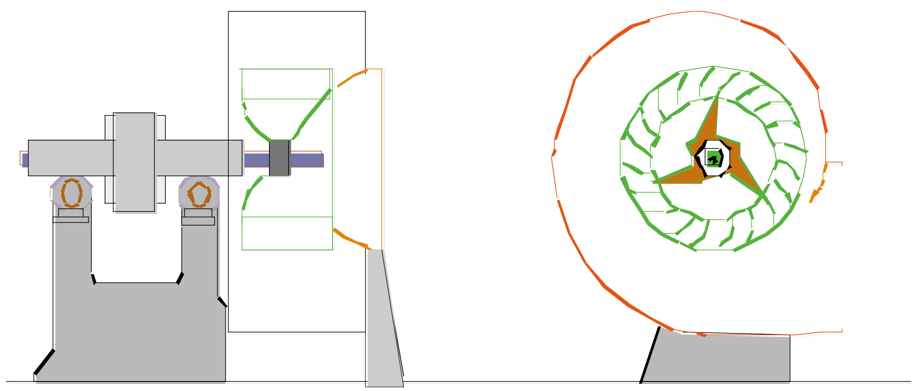
Forward curved blade fans

- Light construction used for heating and air conditioning
- Not suitable for industrial environments
- Produce only low pressures, are relatively inefficient
- Highly vulnerable to dirty air.



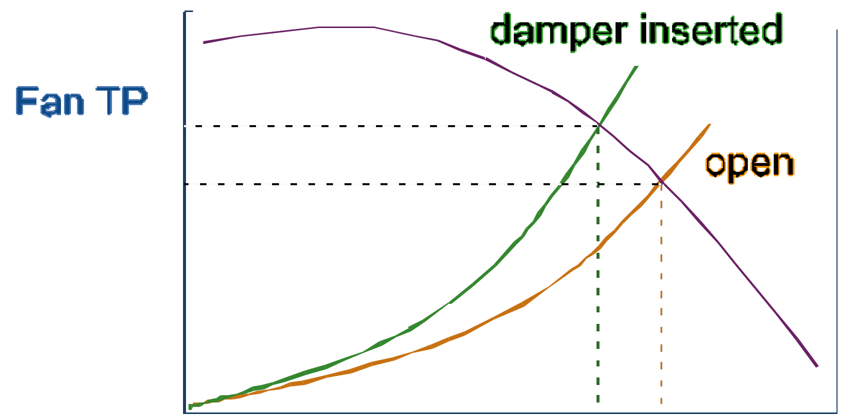
Backward inclined fans

- Produces high pressures
- Quietist and most efficient
- Fouls easily from dusts and any stringy, abrasive or sticky material.
- Protects the motor -- the power required for a backwardly-inclined blade fan peak in the middle of its range. "non-overloading"



Changing airflow

- Changes in system resistance to flow (e.g., using a damper). Power consumption will fall as the damper pushed in, but not decrease as much as when rotation rate decreased.
- Changing rotation rate with pulleys, var. freq. drives, or shivs. Rotation rate cannot be increased without limit due to the increasing strain on the structure of the fan.At elevated temperatures, the maximum allowable rotation rate will decrease.
- Inlet vanes: pre-spin changes apparent rotation rate



Using Fan Tables

- The fan tables generally cover efficient range and avoid the unstable range. High rotation rates are sometimes highlighted.
- Several sizes of the same fan are capable of operation in the desired range. Efficiencies about the same for 2 or 3.
- "Biggest" is not always best: 1) a larger fan is usually more expensive to purchase than a smaller fan, and 2) an additional static pressure load may require the selection of a smaller fan.
- Determining Rotation Rate and Power from the Fan Tables
- Vendor's tables will show w and Powerbrake as dependent variables in a chart of Q and fan pressure.

$$\text{Table } Q = \text{actual } Q$$

$$\text{Table pressure} = \frac{\text{fan pressure} + \text{system effects}}{df}$$

$$\text{Table value} = \frac{\text{actual brake power}}{df}$$

Fan Installation

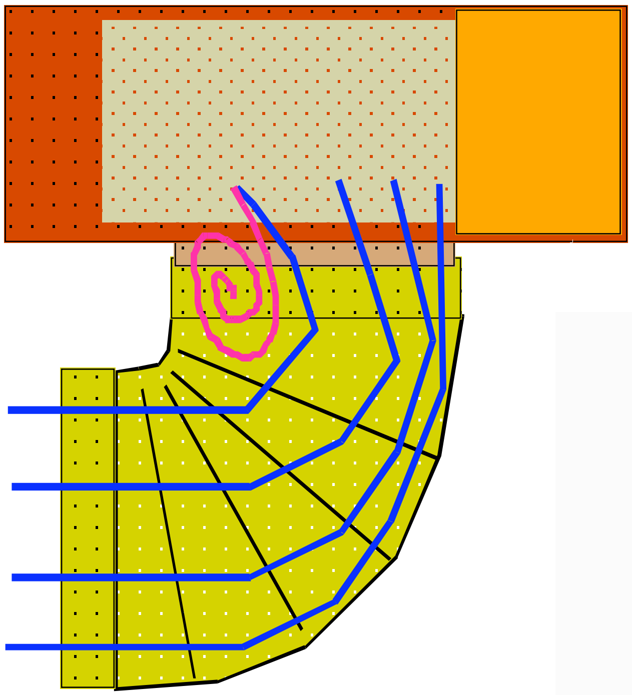
- The fan inlet and outlet ducts must fit the fan. For the most accurate results, we should recalculate Fan SP and Fan TP for each possible set of duct sizes.

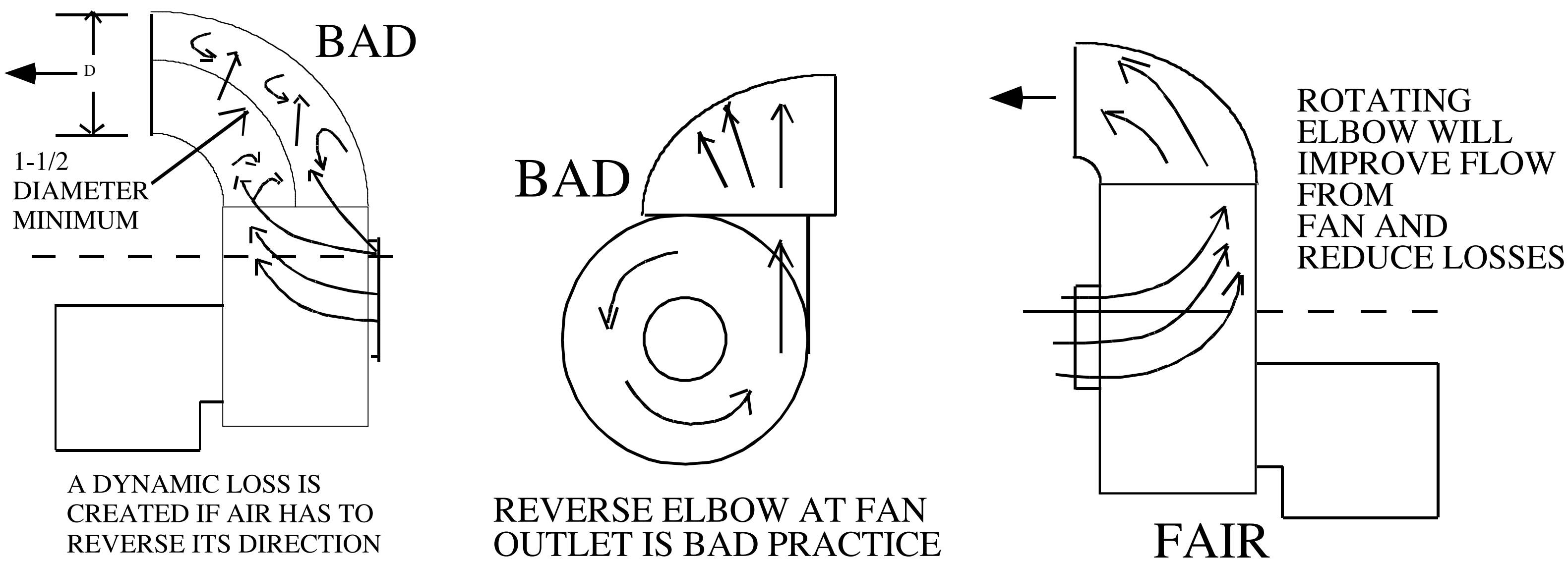
- The fan should be installed so that five conditions are met:
  - Outside the building on ground or built-up roof
  - Good inlet conditions.
  - Good outlet conditions
  - Good vibration isolation.
  - Workers not exposed to excessive noise levels from the fan.

- These conditions are easily met if the designer plans for them before installing the fan or the system.

System Effects on Fan Performance

- Fans perform at their rated level only if the wheel is loaded evenly by the incoming air and when straight duct is connected to the outlet of the fan.
- Inlet conditions: Less airflow if non-uniform loading (eddies, pre-spin, skewed). Need at least 5D of straight duct, but diminishing returns.
- Outlet conditions: The exhaust duct should fit the fan exhaust, and it should be straight and without elbow or obstructions for at least 4 duct diameters in length. Having no exhaust duct reduces fan performance.

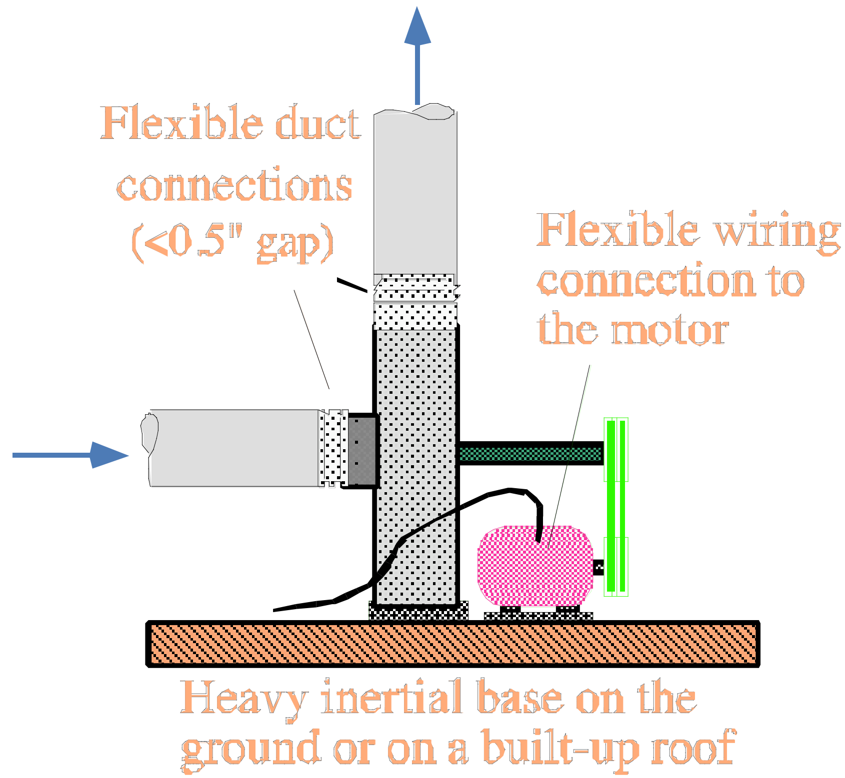




BAD
D
1-1/2
DIAMETER
MINIMUM
A DYNAMIC LOSS IS
CREATED IF AIR HAS TO
REVERSE ITS DIRECTION
BAD
REVERSE ELBOW AT FAN
OUTLET IS BAD PRACTICE
ROTATING
ELBOW WILL
IMPROVE FLOW
FROM
FAN AND
REDUCE LOSSES
FAIR

Locate the fan outside

- The fan must be located outside the building, either on the roof or on the ground. It can be protected from the weather with a protective shed or by outdoor construction. Consult the fan vendor.
- An outside location is usually less encumbered by surrounding structures and machinery, allowing freer access for maintenance and repair.
- Vibration base:
- The base for the fan must be heavy enough (>6 fan wheel weight) to isolate vibration and to reduce resonance. Bulk is not a substitute for weight.
- For particularly large fans, the vendor or a vibration expert should be consulted about vibration isolation.
- Electrical wiring should be flexibly mounted, or it will gradually work loose.
- The inlet and outlet ducts will vibrate unless connected to the fan by flexible sleeves of canvas or rubber. The gap between the duct and fan inlet should be no more than an inch.



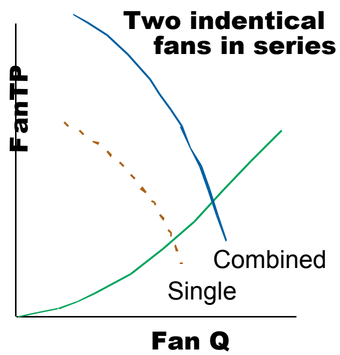
Fan Noise

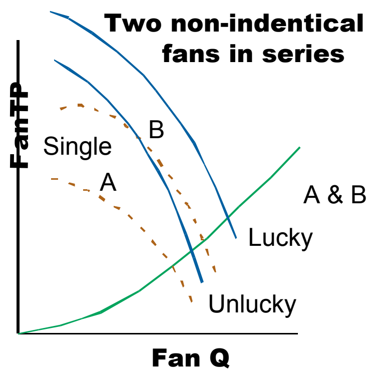
- Problems often can be solved by moving the fan out of the building or work area.
- Choose duct that is 2" larger in diameter than the fan inlet and 10 diameters in length.
- Inside the duct, glue or affix securely to its skin a 1" thick sheet of tough polyurethane foam or commercial sound absorbing material.
- If corrosive atmospheres, line the polyurethane with a thin, protective sheet of plastic or purchase appropriate commercially prepared sound absorbers designed for such atmospheres.
- Backwardly-inclined fans are much quieter than radial blade centrifugals and vane-axial fans. If fan noise is critical, consider an "airfoil" backwardly-inclined blade fan, whose blade tips and air cut-off are shaped as airfoils, which minimizes air shear.

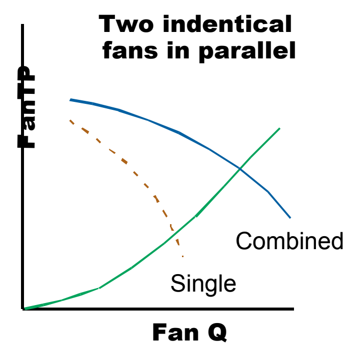
Fans in Series & Parallel

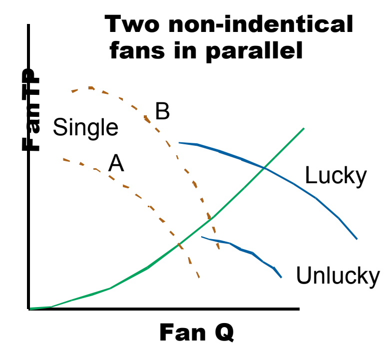
- Two identical fans in series each "see" half of the system pressure, and operate at that pressure on their fan curve. Identical fans in parallel each experience the full system pressure, and each produces airflow at its rated level for that pressure. Non- identical fans in parallel or series produce less than one alone, yet consume excessive energy. Worse, one or both may become unstable.

- Fans should never be installed in parallel except for standby, redundant fans which are shut off and blocked from the system until needed. "Helper" fans should never be installed on branches or submains: such practices make for entertaining anecdotes for ventilation troubleshooters.


Two indentical
fans in series
FanTP
Combined
Single
Fan Q


Two non-indentical
fans in series
FanTP
Single
B
A
A & B
Lucky
Unlucky
Fan Q


Two indentical
fans in parallel
FanTP
Combined
Single
Fan Q


Two non-indentical
fans in parallel
FanTP
Single
B
A
Lucky
Unlucky
Fan Q

Drive systems

A motor can drive the fan directly so that the motor and fan blade are on the same shaft, or the motor can drive the fan indirectly with a belt:

- Direct drives used for small motors or where airflow need not change with time and low first cost is paramount.Direct drives have no belt to slip and no transmission inefficiency but are more difficult to adjust speeds. Maintenance complicated by the fact that the motor and fan share the same shaft.
- Indirect drives are more expensive than direct drives and waste about 10% of the energy from the motor, but provide flexibility in changing fan speed. Easier to service indirect drive fan systems, the frequency of maintenance will be much greater - the belts must be re-tightened or replaced periodically.
- Many indirect drive transmission use adjustable shiv pulleys, usually on both shafts. Both shivs must adjust or have idler. Adjusting the angle of the crotch of a pulley, the apparent diameter of the pulley changes, changing the rotation rate of the fan without having to remove the belts and replace the pulley.

Selecting fan motors

The motor does whatever is asked of it. Its rating is a guide to over-heating. Cheaper for incremental ratings. Allow for excess capacity, but a grossly under-loaded motor will be inefficient. On higher phase motors, use watt-meter since voltage can drop.

<u>Table 4a: List of Incremental Motor Sizes by HP</u>

1	1.5	2.5	3	5	7.5	10	15	20
	25							
30	40	50	60	75	100	125	150	200

<u>Table 4b: Quality Levels</u>

Level	Description
Lowest	Open, drip-proof. Not suitable for outdoors, dusty areas, etc.
Middle	Totally enclosed, fan cooled (T.E.F.C.). Shaft extends through back of motor; has propeller in rear to cool motor
Highest	Explosion proof. A.M.C.A. rating A, B, or C with PVC propeller.

Safety

- Fans are extremely dangerous, especially for maintenance personnel. The fans should not operate without all guards in place. The rotating shaft will wrap up loose ends of clothing or hair and can easily amputate limbs or pull off the scalp. The fan motor should be securely locked out during maintenance of the blades or when inspecting inlet conditions or any other time inlet or outlet ducts are removed.

- The lighting for the fan location should be on a separate circuit from the fan itself for obvious reasons.

Troubleshooting

- Check rotation rate for slippage.
- Align and tighten V-belts.
- Check the wheel and inlet cone alignment.
- Clean the fan blades.
- Direction of rotation.
- Compare power consumption to motors rated level.
- A centrifugal fan rotating backwards will push air in the correct direction, but at 1/3 to 1/2 its rated level. Electricians should be instructed to check direction of rotation after wiring a fan.

Air Cleaners

COLLECTORS - SELECTION

PARTICLE SIZE

% REMOVAL

HIGH TEMPERATURE

CORROSIVE AIRSTREAMS

PARTICLE SIZE VS COLLECTOR CHOICE

SIZE - M	METHOD
~ 100	settling
> 1	impact fabric
< 0.5	diffusion
0.01 - 5	electrostatic

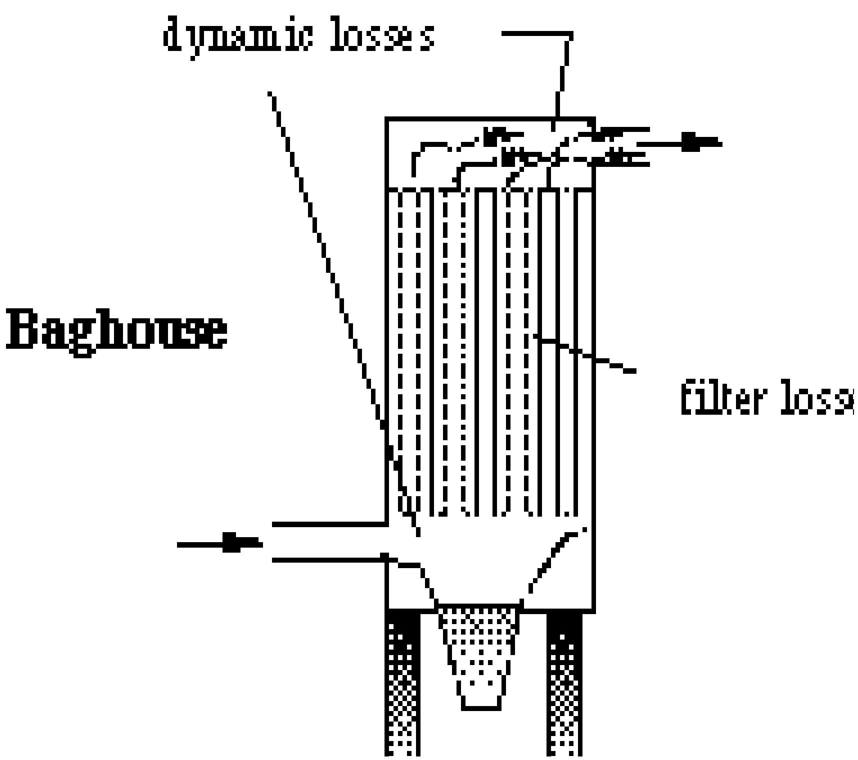
COLLECTORS - COST

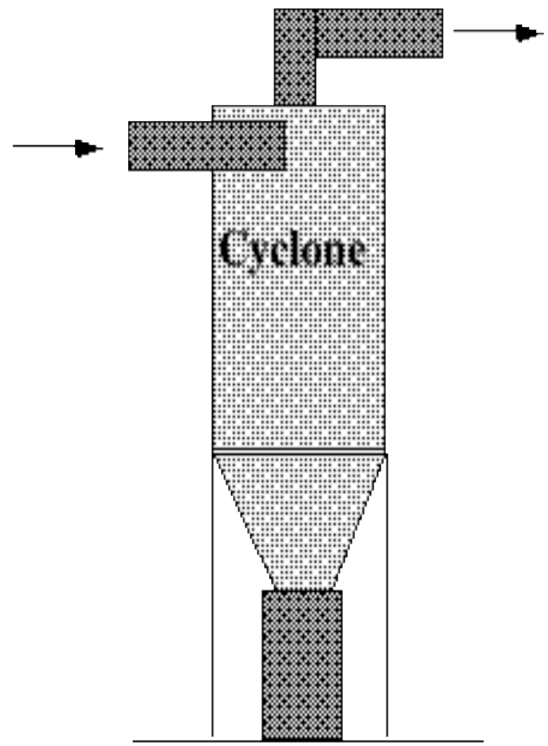
VOLUME

% REMOVAL

PARTICLE SIZE

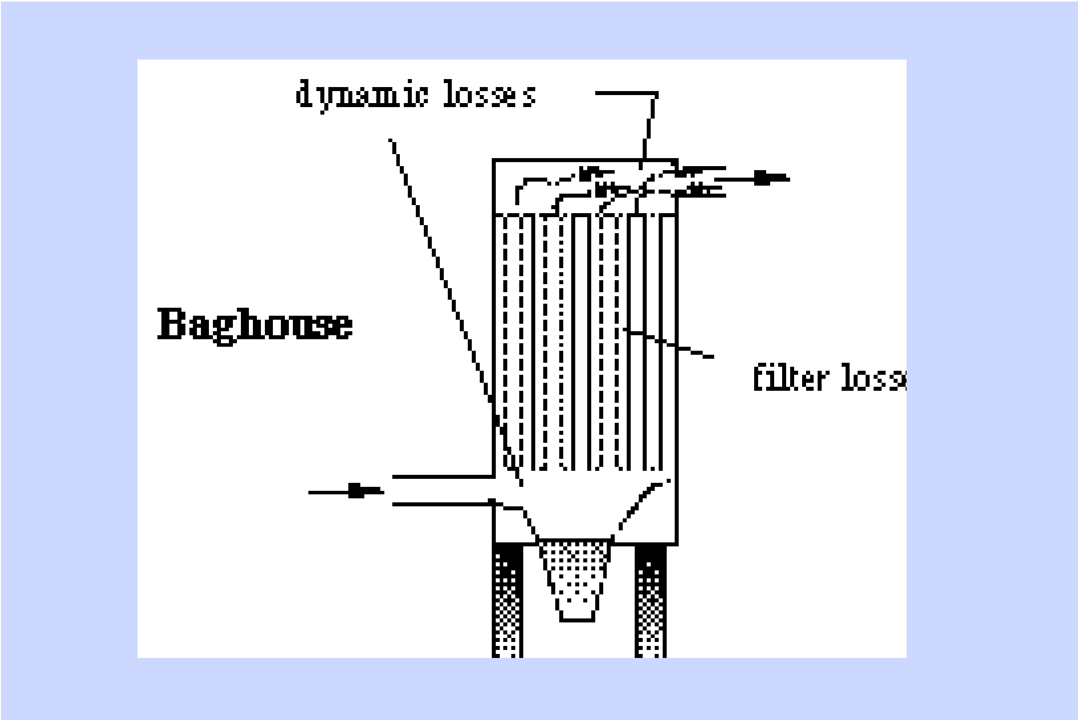
Air-Cleaner Losses



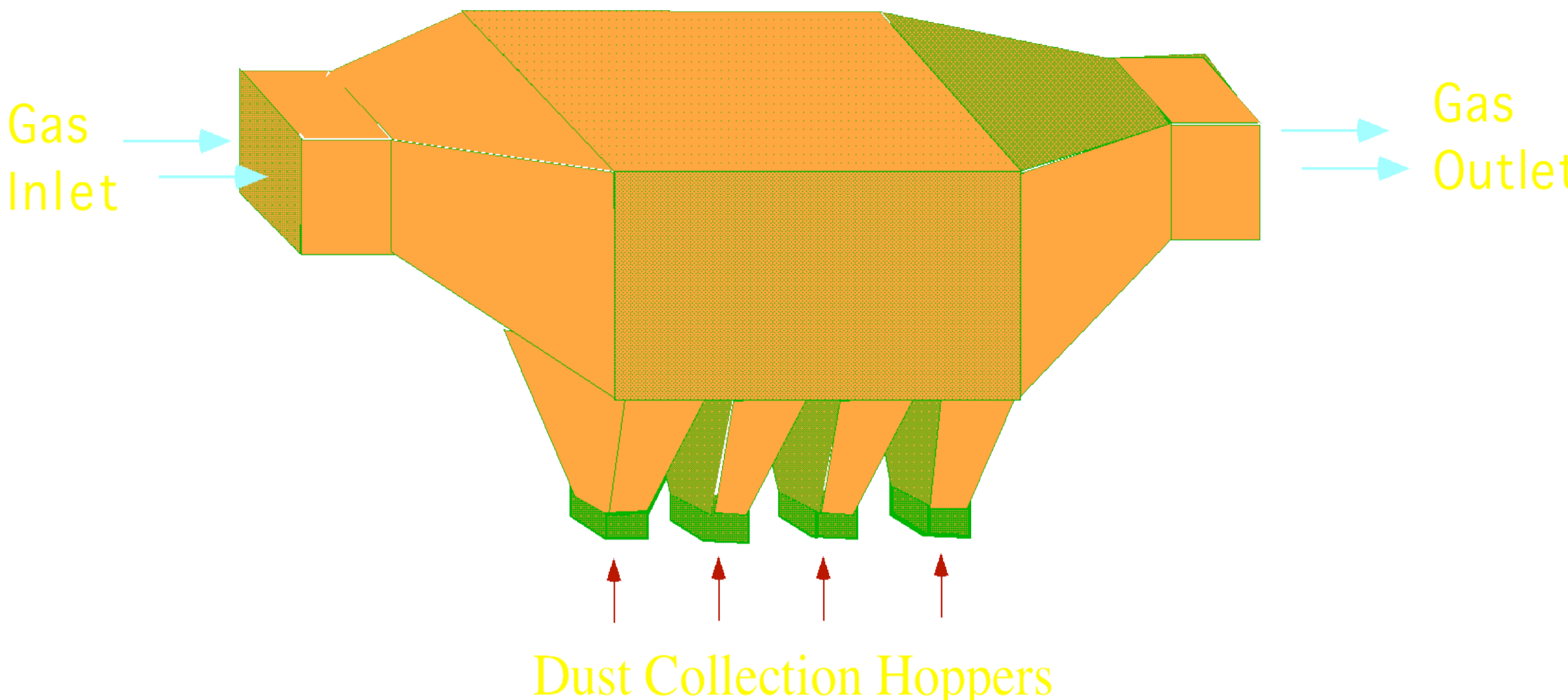


Filter loss linear with Q
Dynamic losses Q squared

Baghouse



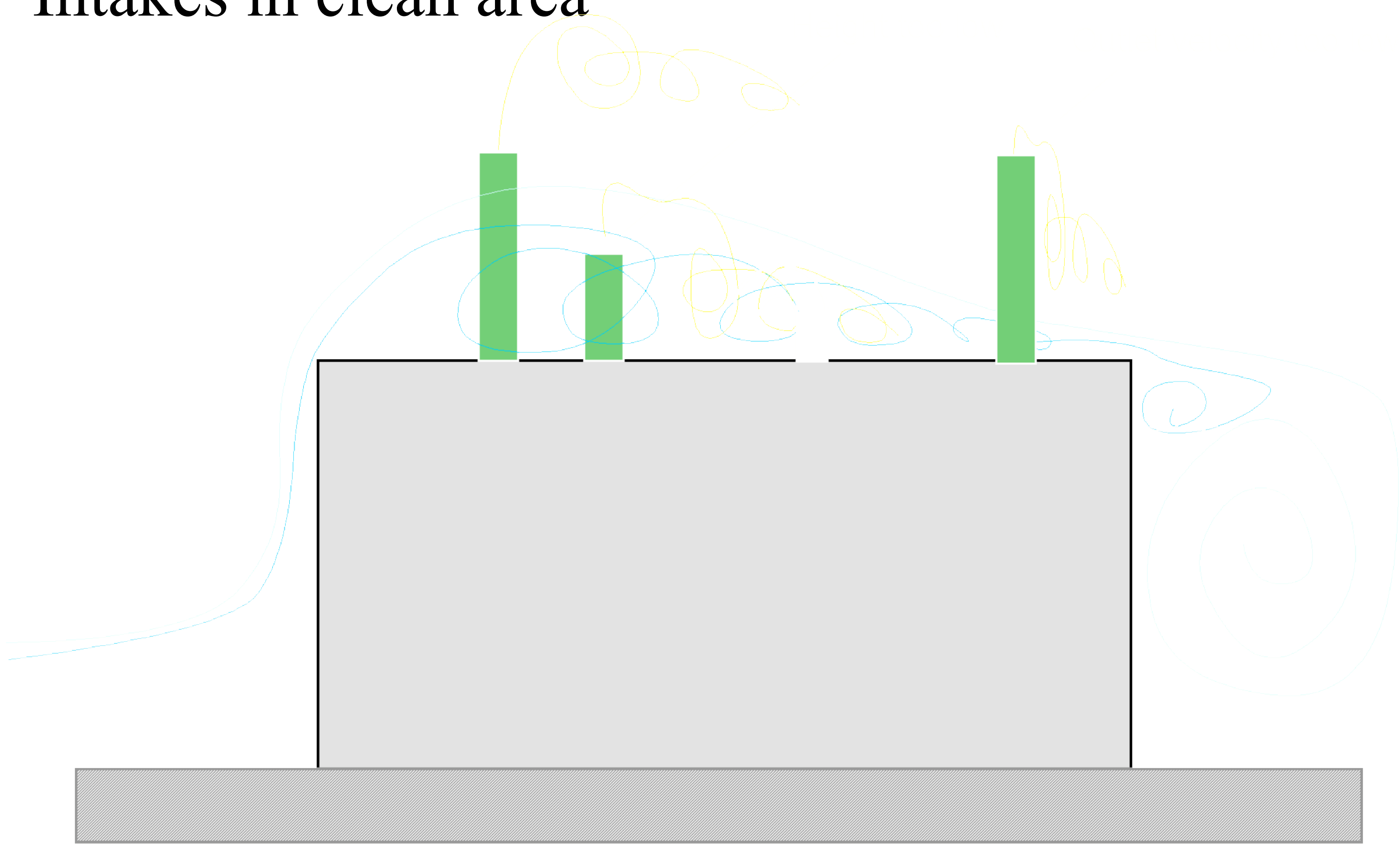
Horizontal Flow Settling Chamber



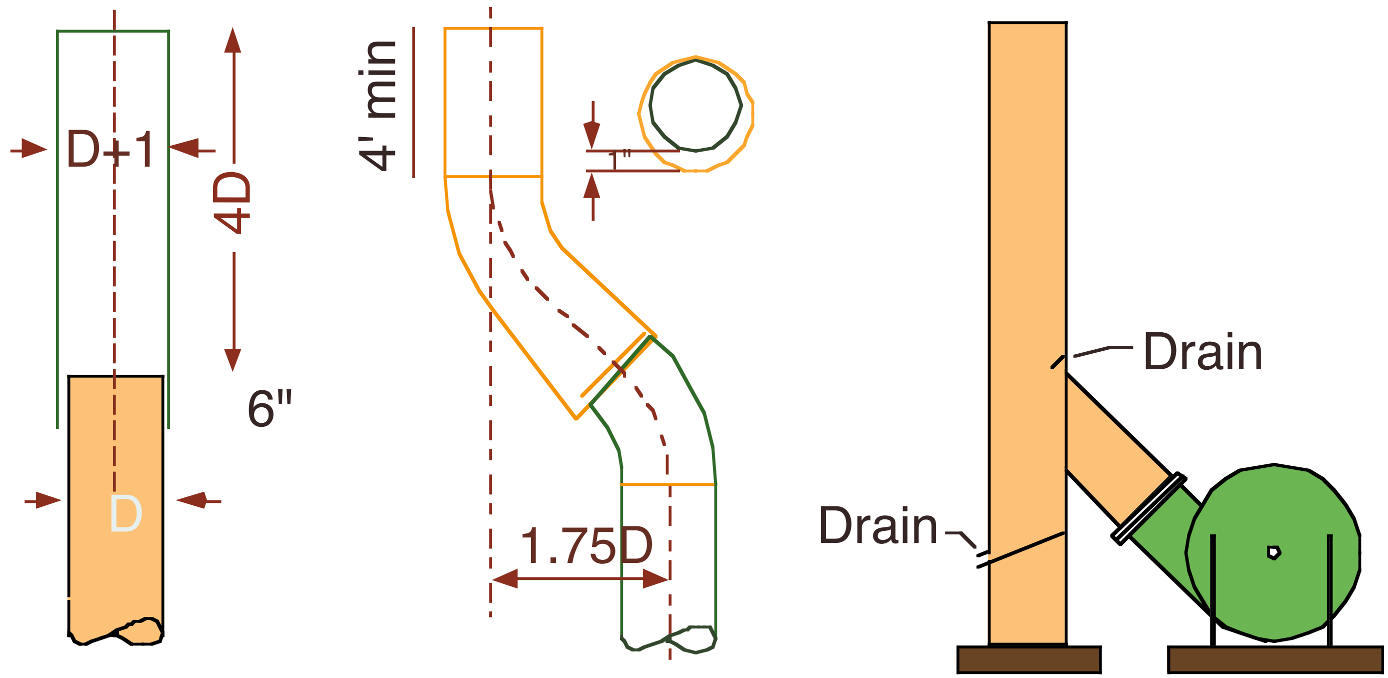
- Cut diameter > 100 um
- Much blows across if no impaction plate
- Suitable for product removal, gross dust pre-cleaning

Stacks and Intakes

- Need height and exit velocity
- Goose neck inlets
- Intakes in clean area



Weather Stacks



Discharge Offset Elbows Offset Stack

Recirculation