CAE 464/517 HVAC Systems Design

Spring 2023

February 14, 2023

Intro to fluid flow and ASHRAE 62.1

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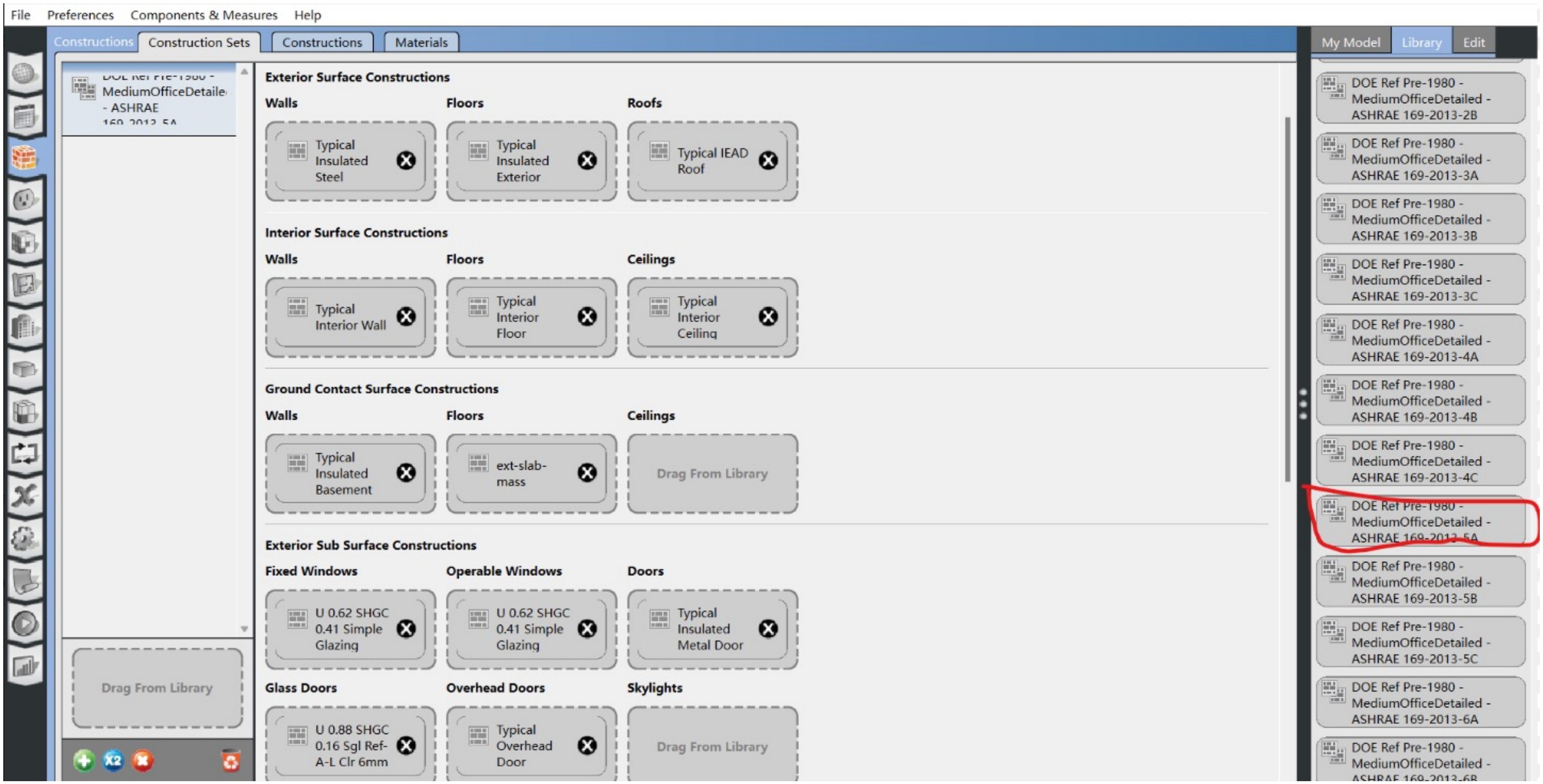
ANNOUNCEMENTS

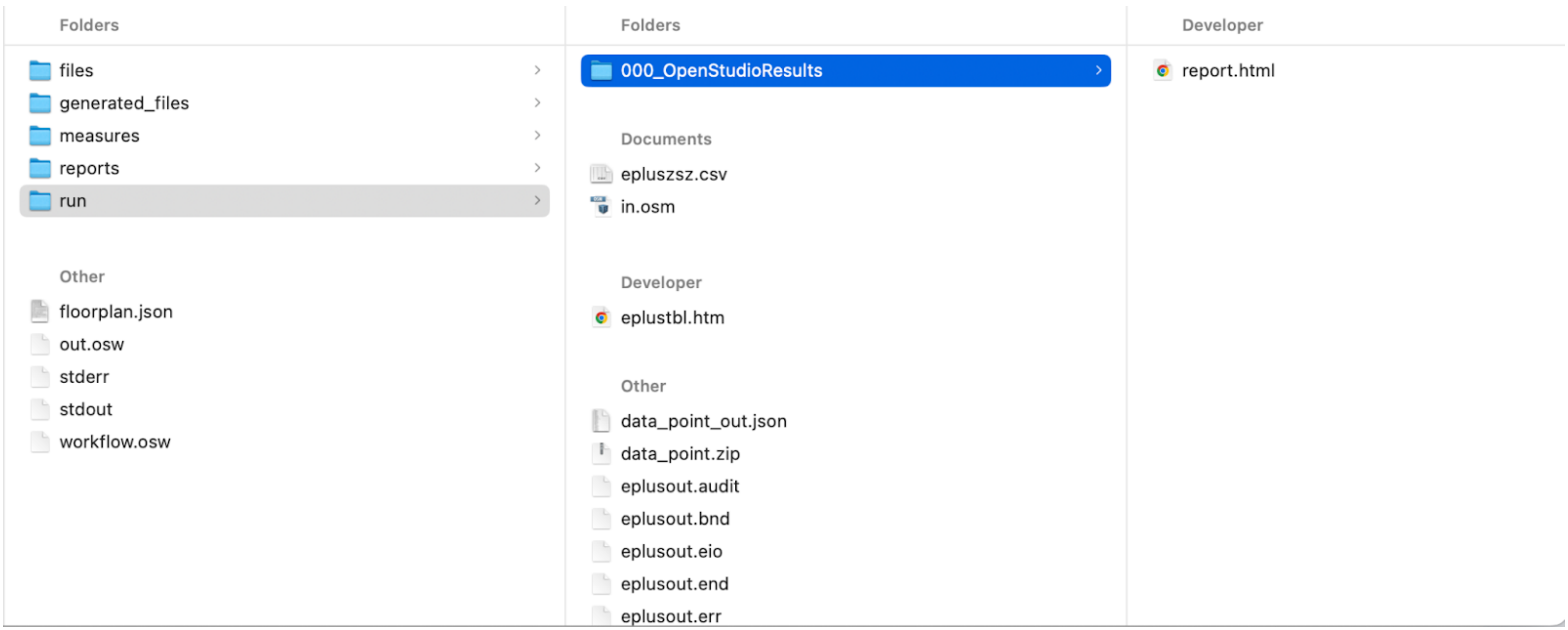
Announcements

- Assignment 3 Parts (a) and (b) – Common Mistakes
  - ❑ Make sure to use the write template!



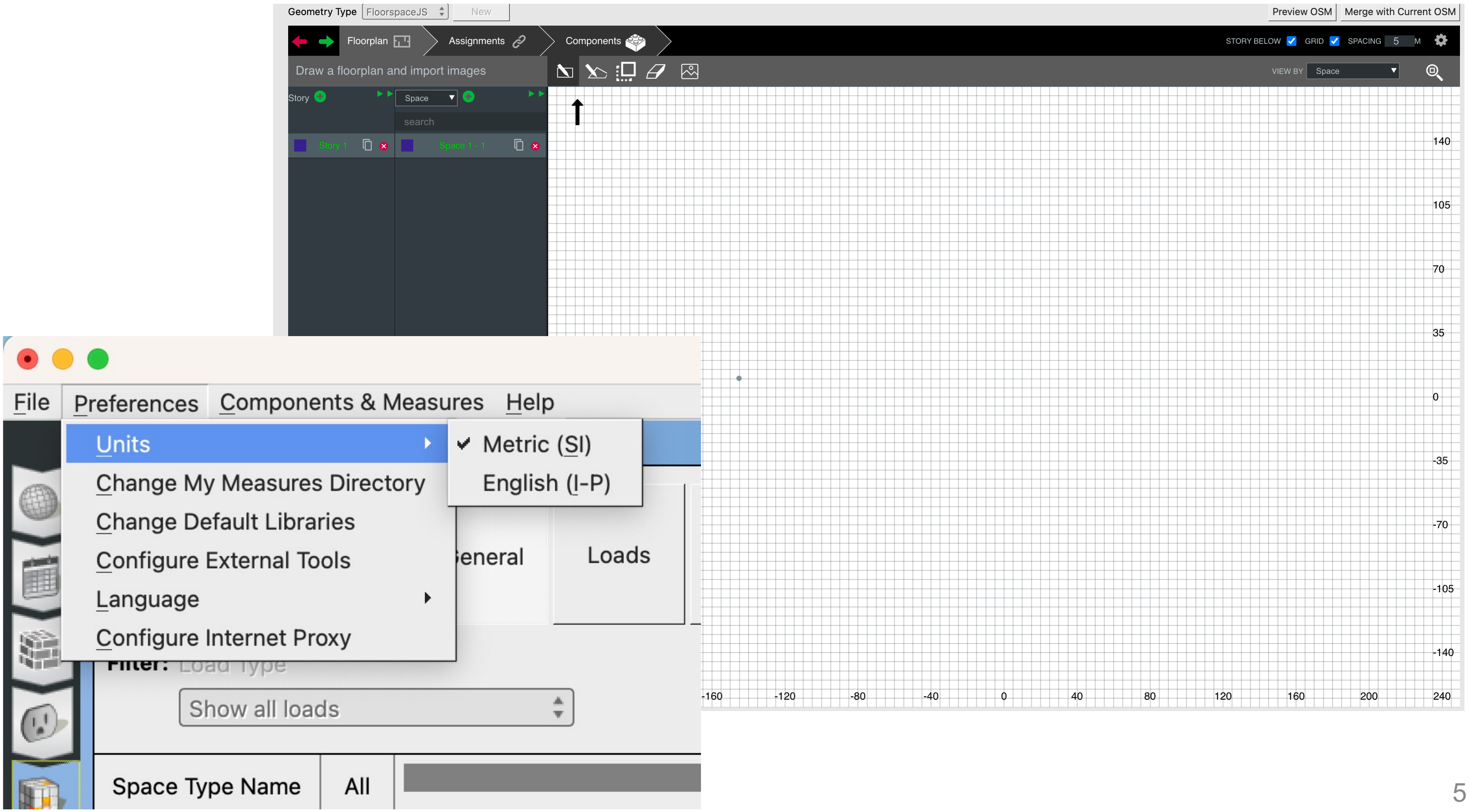
Announcements

- Assignment 3 Parts (a) and (b) – Common Mistakes
  - ❑ Make sure to include the folder



Announcements

- Assignment 3 Parts (a) and (b) – Common Mistakes
  - ❑ Pay attention to the units



Announcements

- Do not forget about the Q&A file:

https://docs.google.com/document/d/1m6ezSI6Bi9wGQcjnaYj_iAXY2kzRlCPYWkKfayNp5WE

Announcements

- Any questions for Assignment 3 Parts (c) to (e)?

Announcements

- Group project: Add your name to the list

https://docs.google.com/spreadsheets/d/1WwM6L1i8SmpTWU
3xYQeNypfnqbloQRglBgCt5E7Kb2s/

REVIEW OF FLUID FLOW (CAE 209 OR MMAE 313)

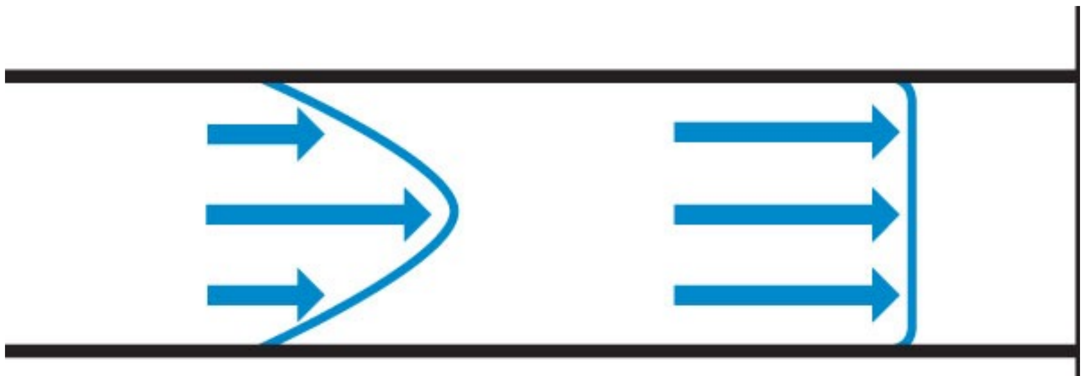
(Please, see Chapter 3 of the handbook)

Fluid Properties

- For fluid properties, in the design, we mostly consider the following assumptions:
  - ❑ Fluids are incompressible
  - ❑ Gases may be compressible or incompressible
  - ❑ Newtonian vs non-Newtonian

Fluid Properties

- Viscosity is the resistance of adjacent fluid layers to shear



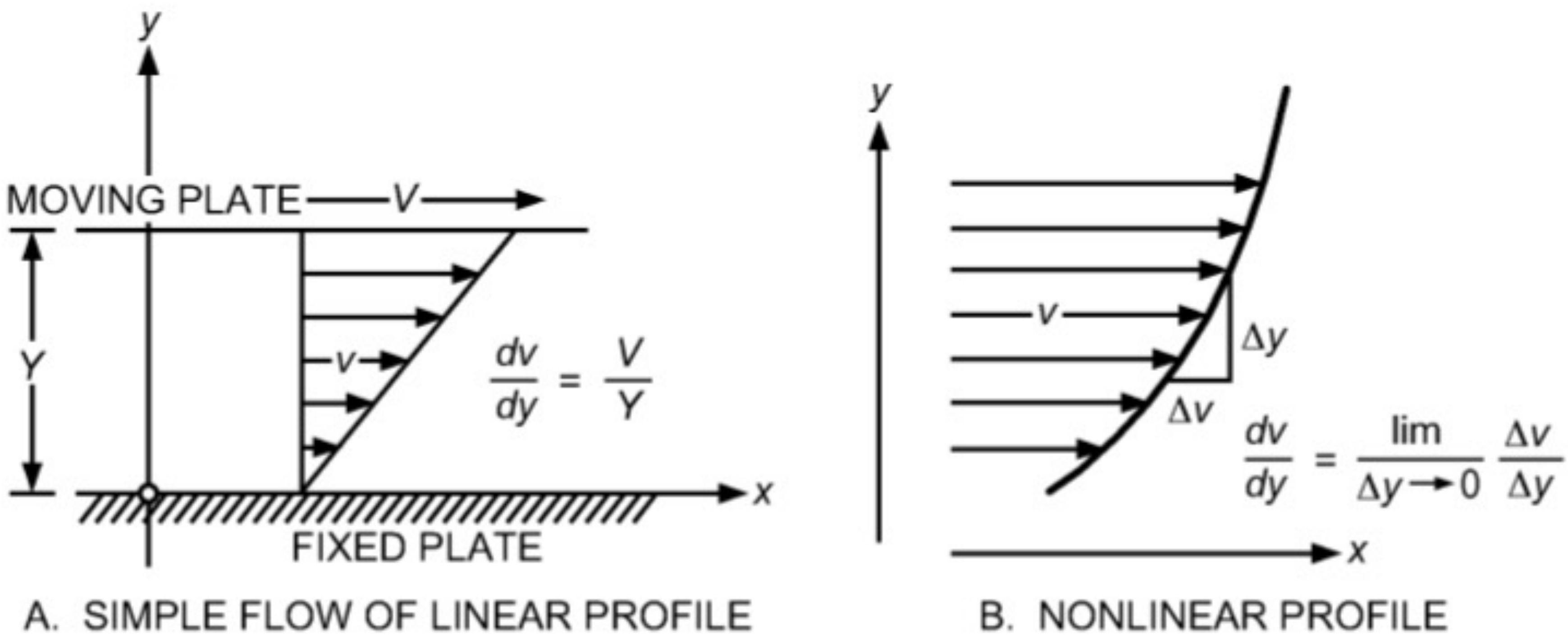
Which one has the high viscosity?

What would an example of each?

https://www.cradle-cfd.com/tec/column05/009.html and https://www.flowmeters.co.uk/high-viscosity-fluid-flow-meters/

Fluid Properties

- Viscosity is defined as:



$$\tau = \mu \frac{du}{dy}$$

Continuity Equation

- Conservation of mass:
  - ❑ Mass flow rate:

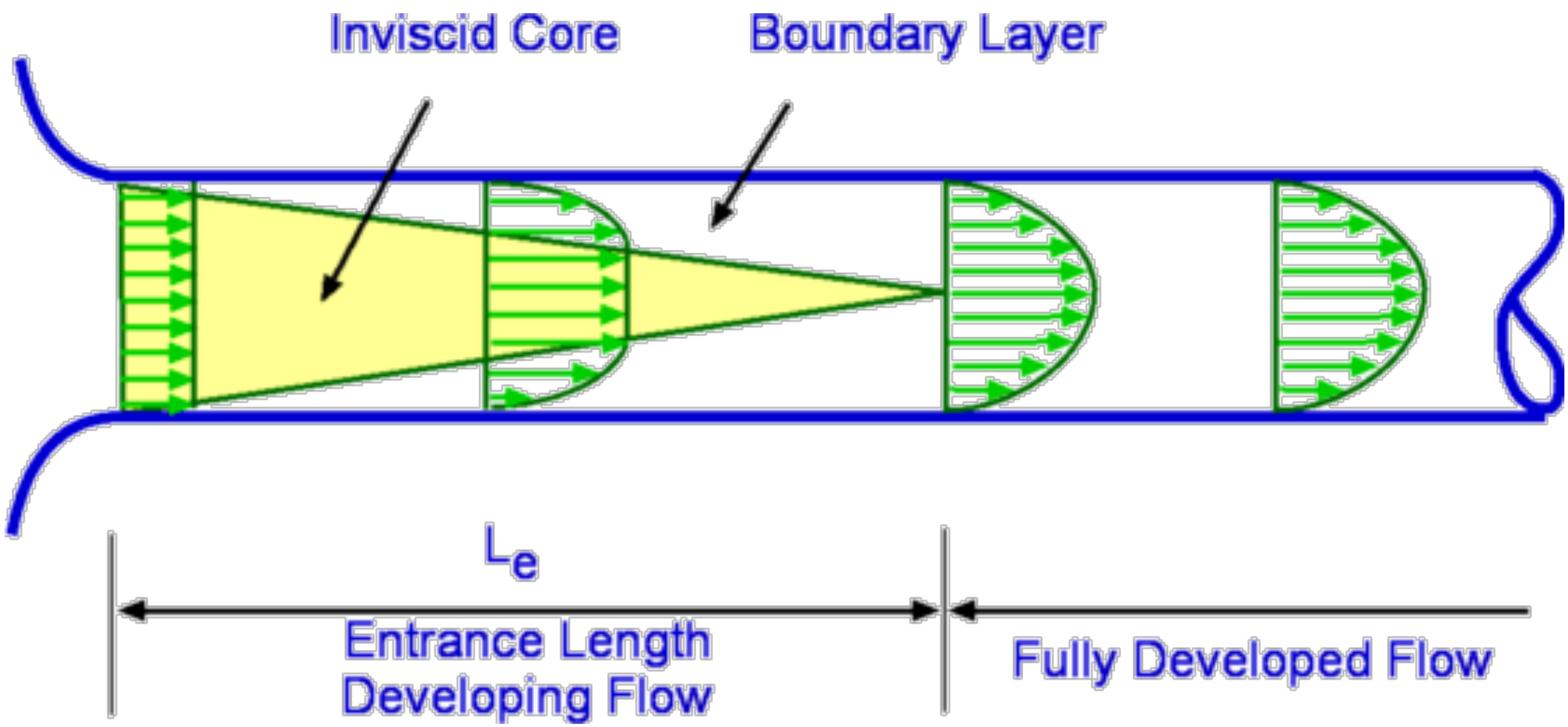
$$\dot{m} = \rho A V$$

  - ❑ Volume flow rate:

$$Q = \frac{\dot{m}}{\rho} = AV$$

Entrance and Fully Developed Regions

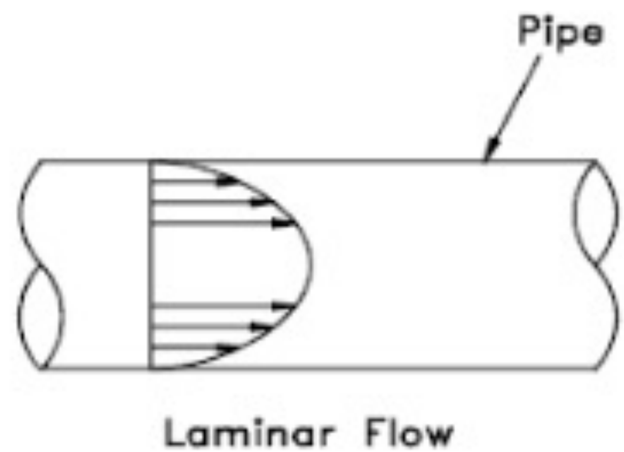
- Consider a pipe flow:



http://www-mdp.eng.cam.ac.uk/web/library/enginfo/aerothermal_dvd_only/aero/fprops/pipeflow/node9.html

Laminar Flow

- Laminar flow is defined as:



$$\tau = \mu \frac{du}{dy}$$

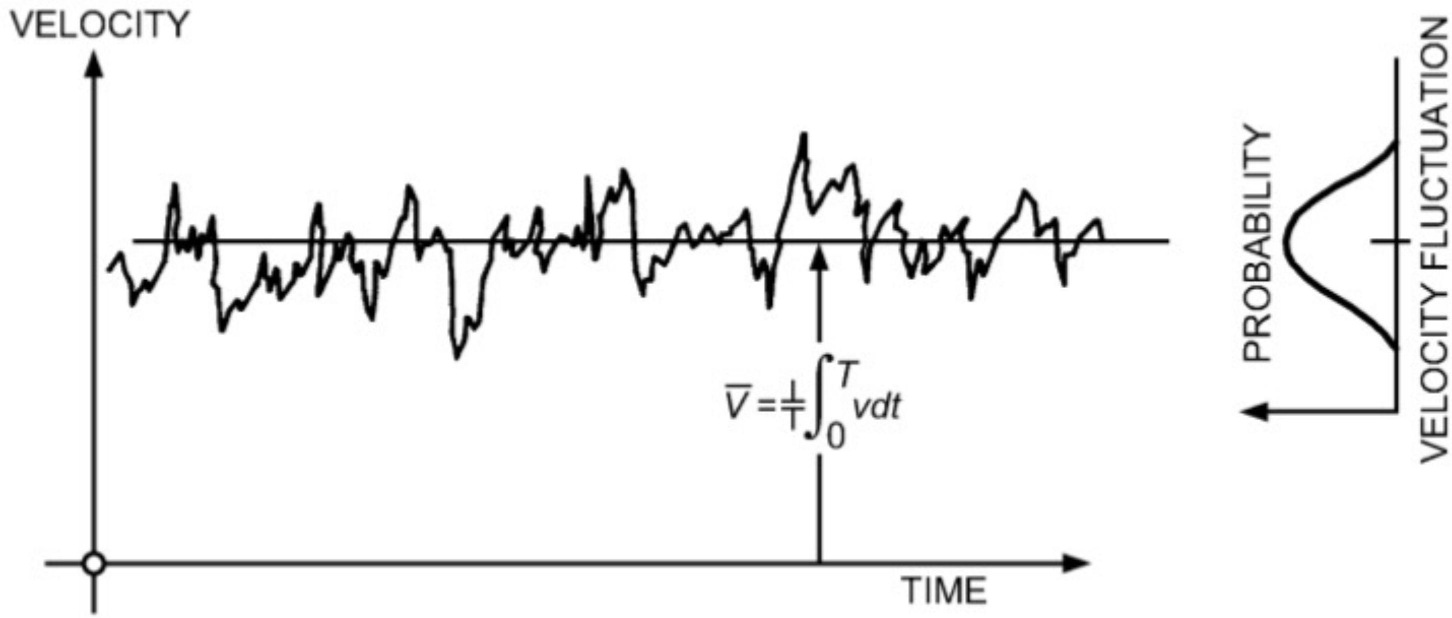
$$\tau = \frac{1}{2} r \Delta P = (Const) \times r$$

- For parabolic flow:

$$u = \frac{1}{4\mu}\left[-\frac{d}{dx}(P + \rho g z)\right](R^2 - r^2)$$

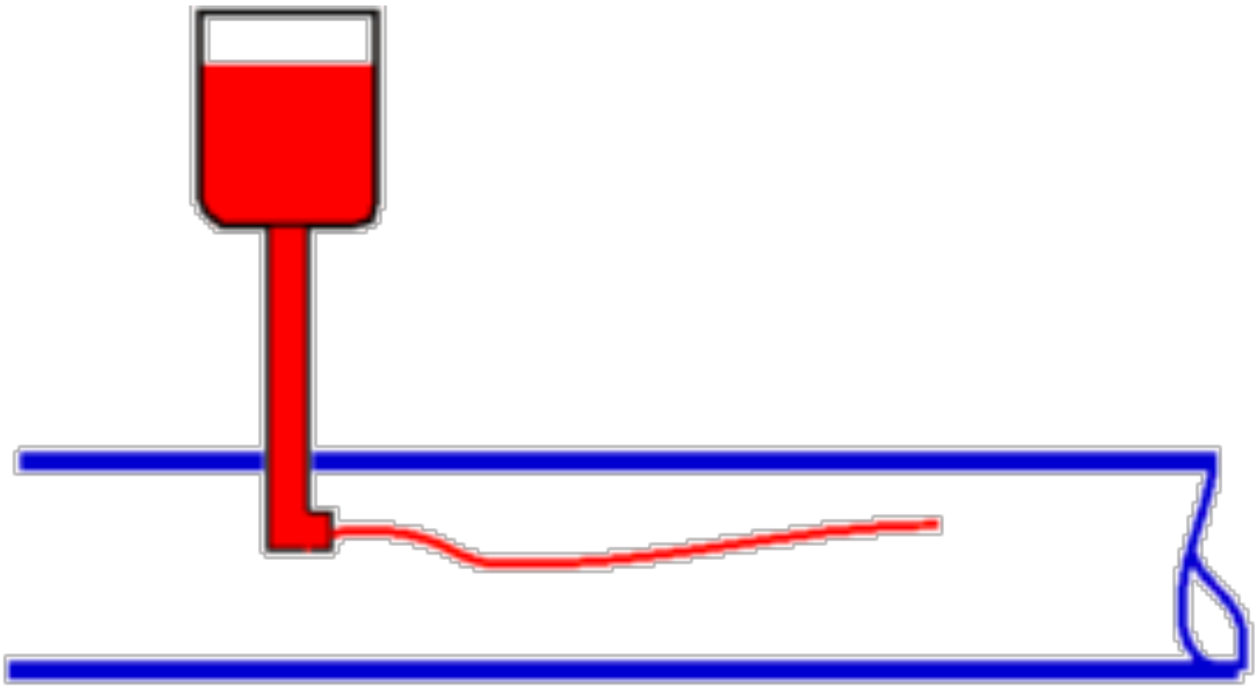
Turbulent Flow

- Turbulent flow is a function of fluctuations



Turbulent Flow

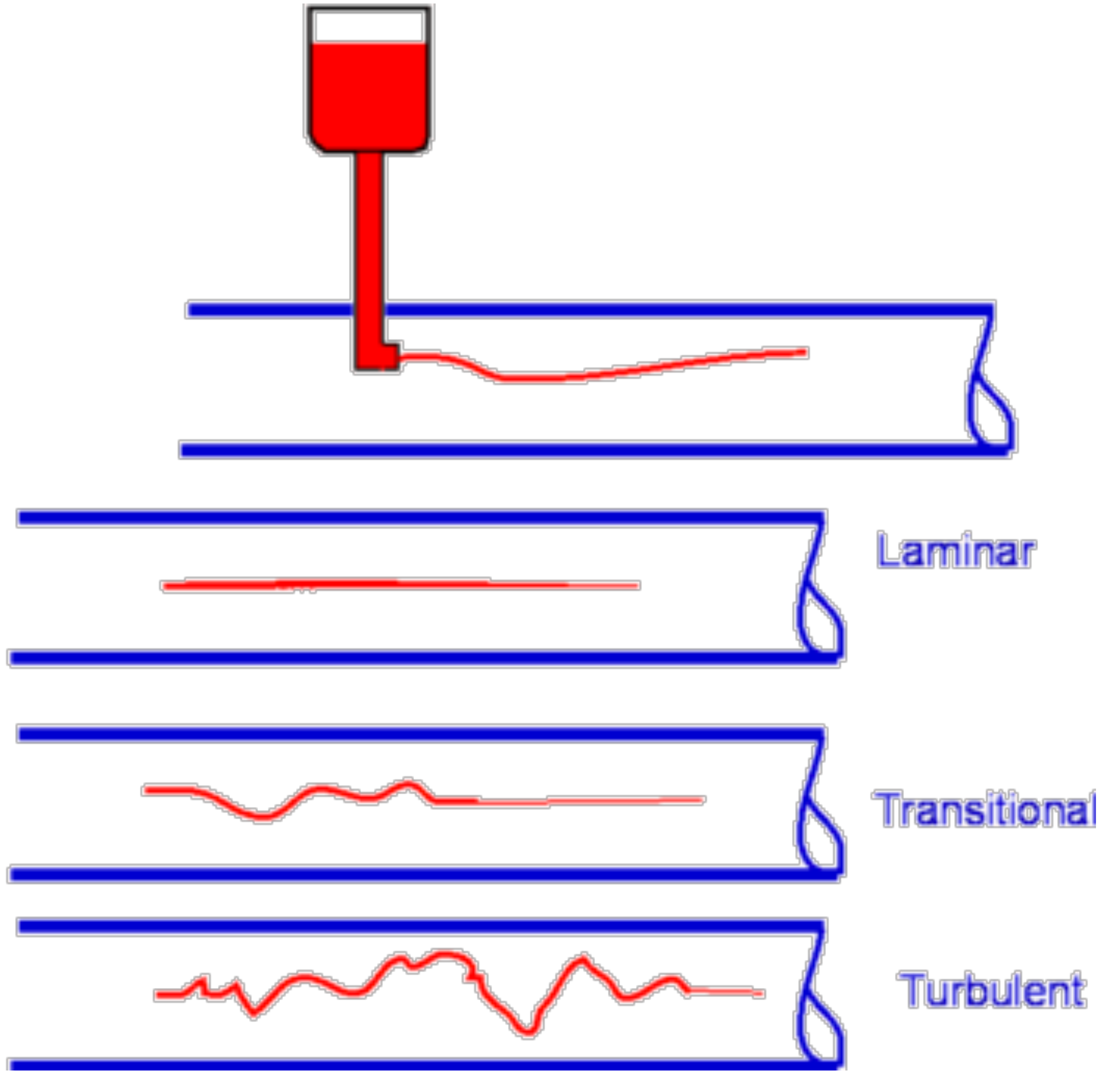
- Reynolds experiment:



http://www-mdp.eng.cam.ac.uk/web/library/enginfo/aerothermal_dvd_only/aero/fprops/pipeflow/node8.html

Turbulent Flow

- Reynolds experiment:



http://www-mdp.eng.cam.ac.uk/web/library/enginfo/aerothermal_dvd_only/aero/fprops/pipeflow/node8.html

Turbulent Flow

- The measure of turbulent vs laminar is

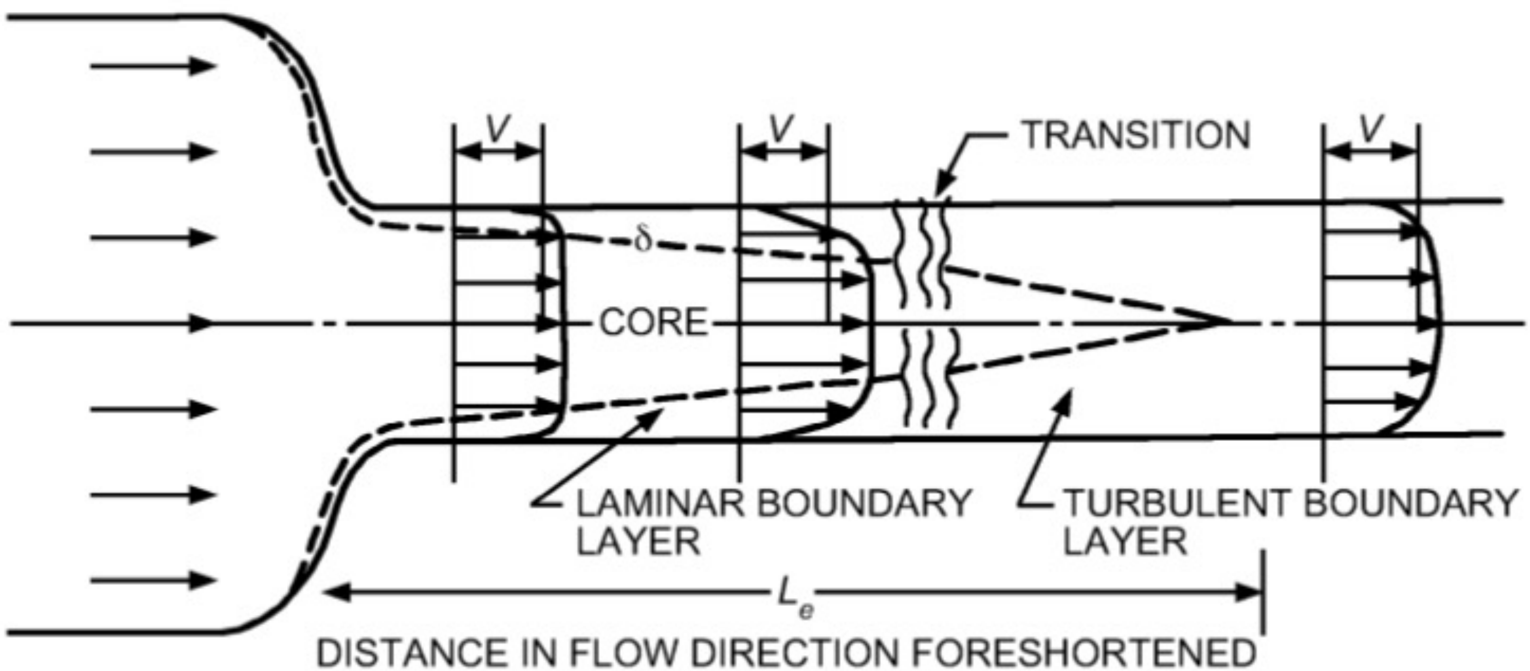
$$Re = \frac{VD}{\nu}$$

- What will happen for rectangular cross section?

Hydraulic diameter $= D_h = \dfrac{4(Cross\ sectional\ area)}{Wetted\ perimeter}$

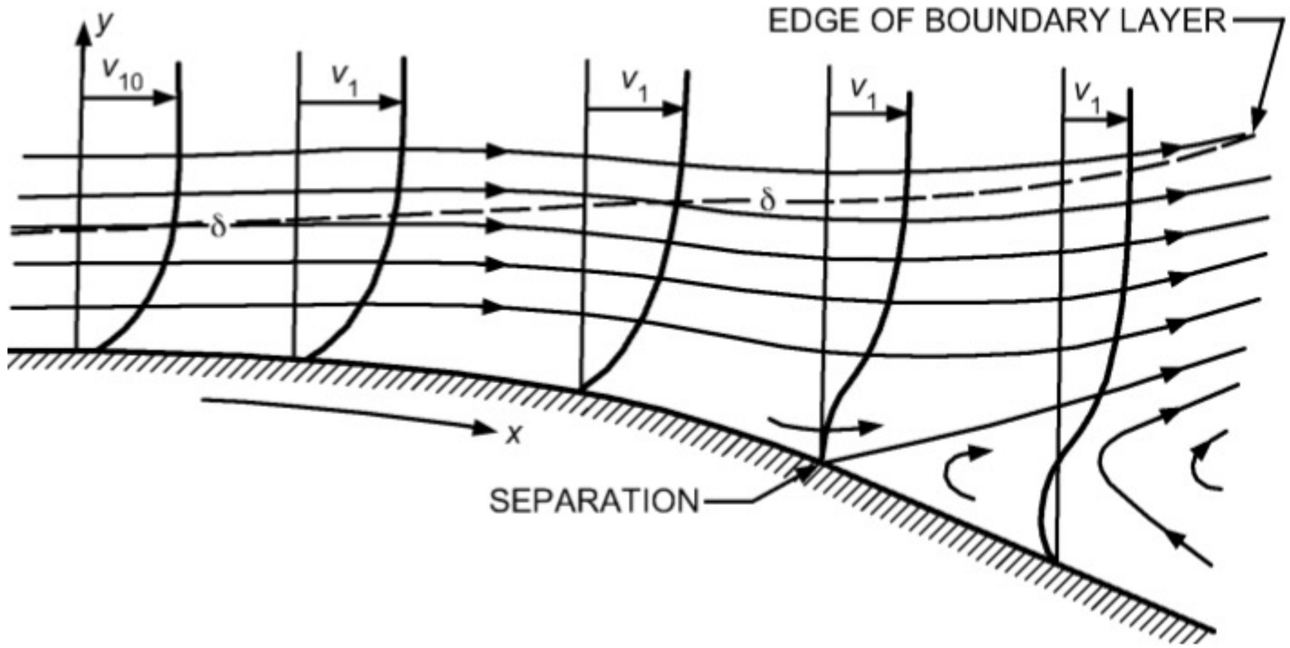
Entrance Region

- Boundary layer effect determines the flow pattern in pipe or conduits



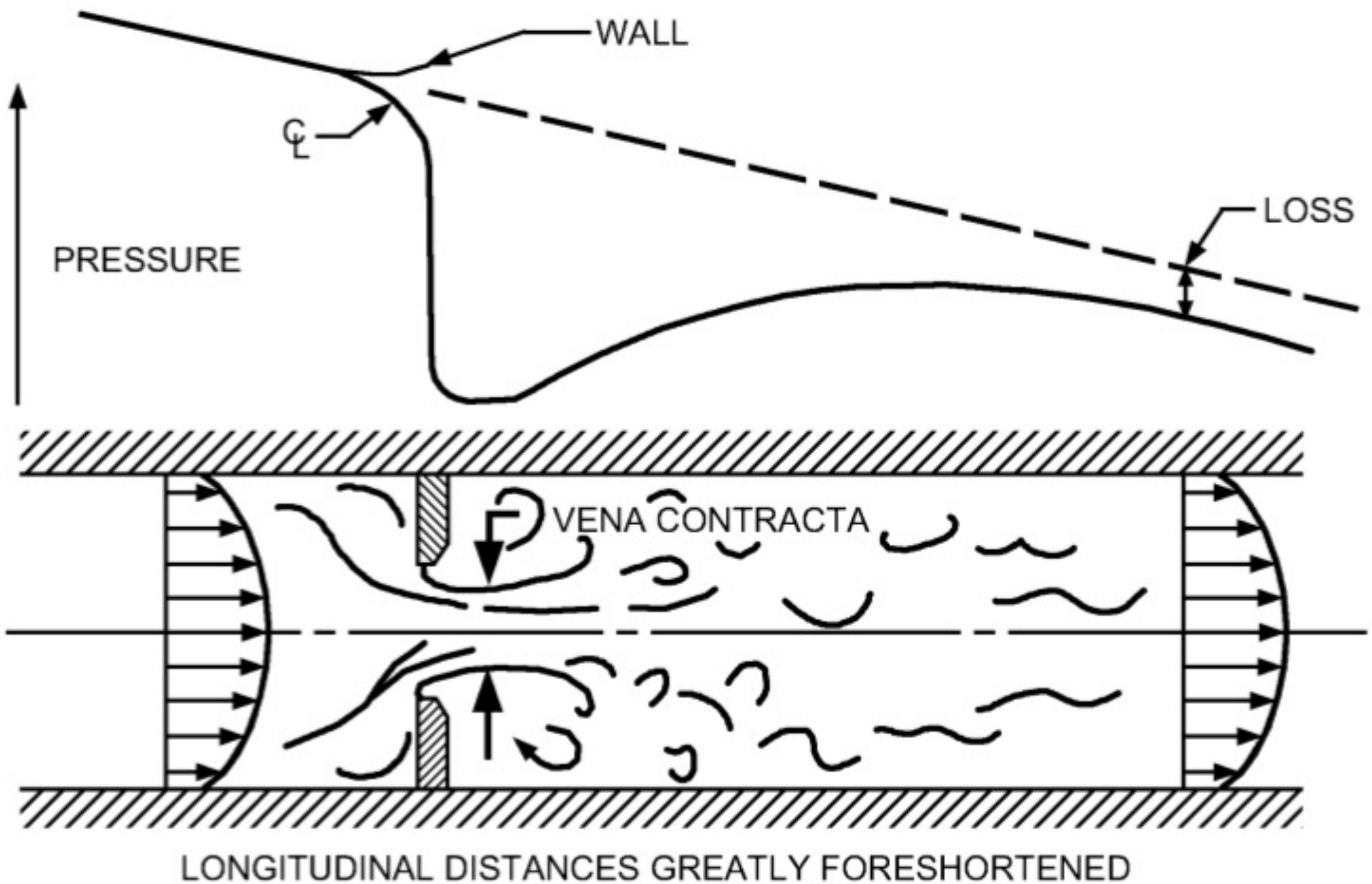
Flow Separation

- There is basically adverse pressure gradient
- Flow cannot follow the surface anymore



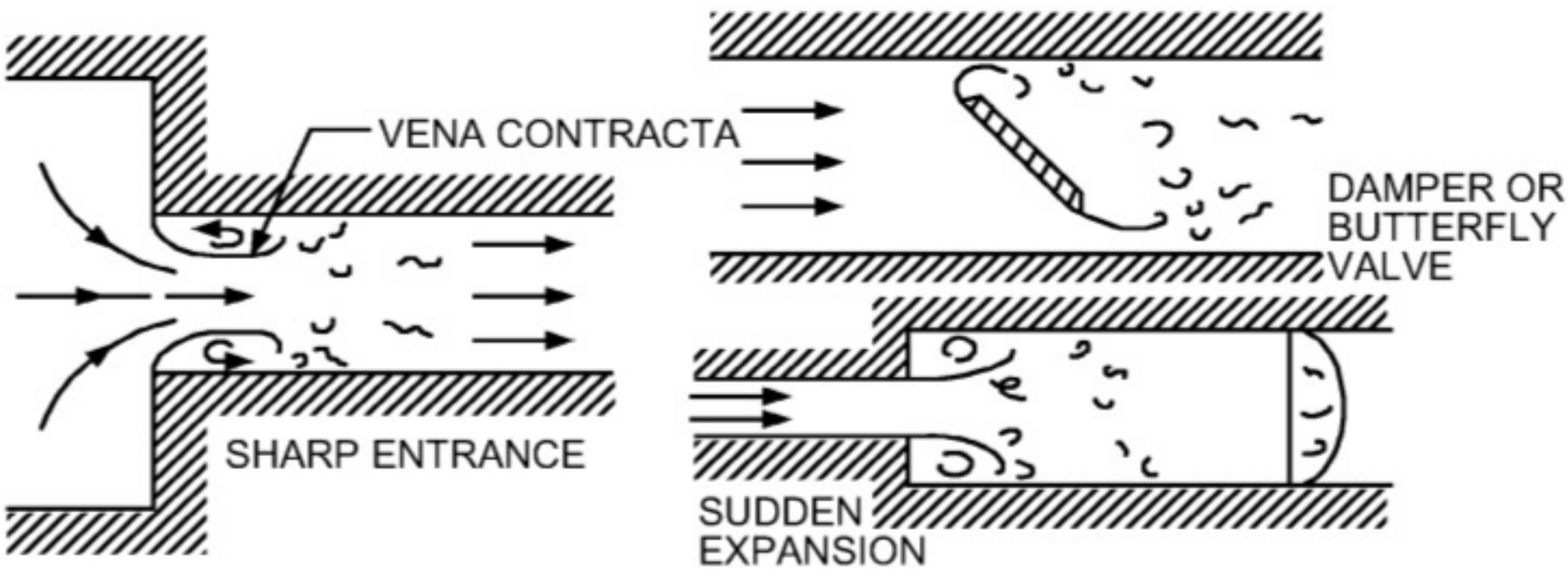
Flow Separation

- Flow separation is one of the sources to losses of flow field



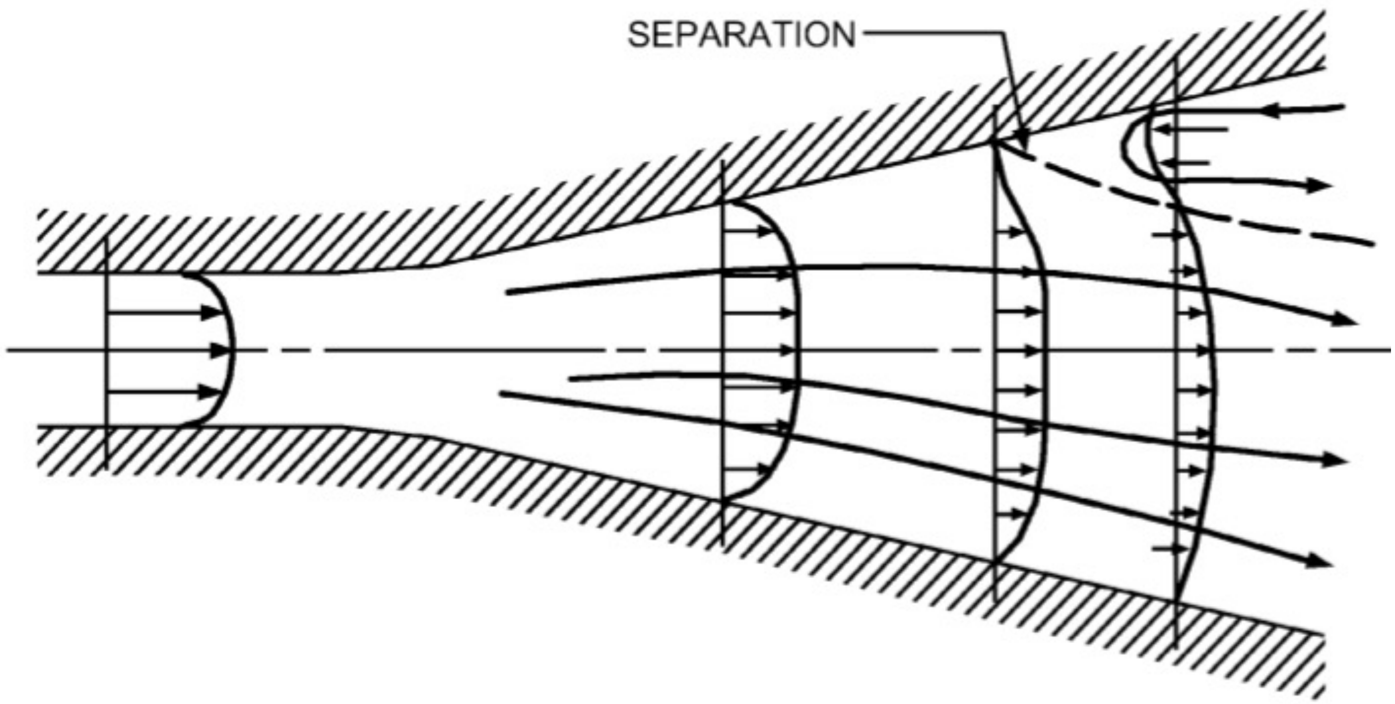
Flow Separation

- Flow separation in
  - ❑ Vena contraction
  - ❑ Sudden expansion
  - ❑ Dampers

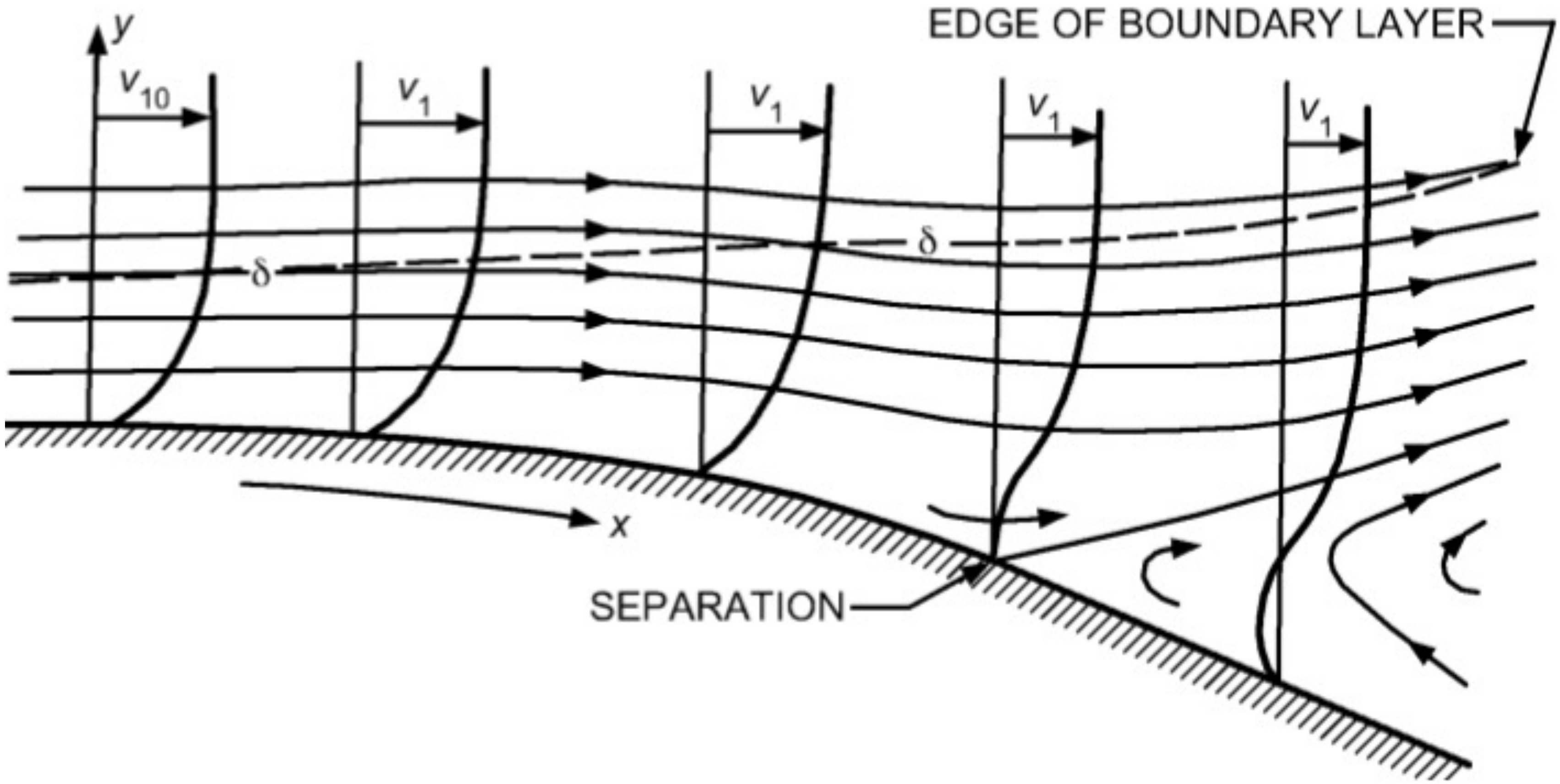


Flow Separation

- Flow separation in diffusers



Flow Separation



http://web.mit.edu/hml/ncfmf.html

Conduit Friction

- Account for friction caused by conduit-wall shearing stresses and losses from conduit section change using H_L or E_L in the energy equation

- H_L is the loss of energy per unit mass of flowing fluid

- Darcy-Weisbach equation:

$$H_{Lf} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

Conduit Friction

- For laminar flow the equation is modified as:

$$H_{Lf} = \frac{L}{\rho g}\left(\frac{8\mu V}{R^2}\right)$$

$$H_{Lf} = \frac{32 L \nu V}{D^2 g}$$

$$H_{Lf} = \frac{64}{\frac{DV}{\nu}}\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

- Darcy friction factor is:

$$f = \frac{64}{Re}$$

Conduit Friction

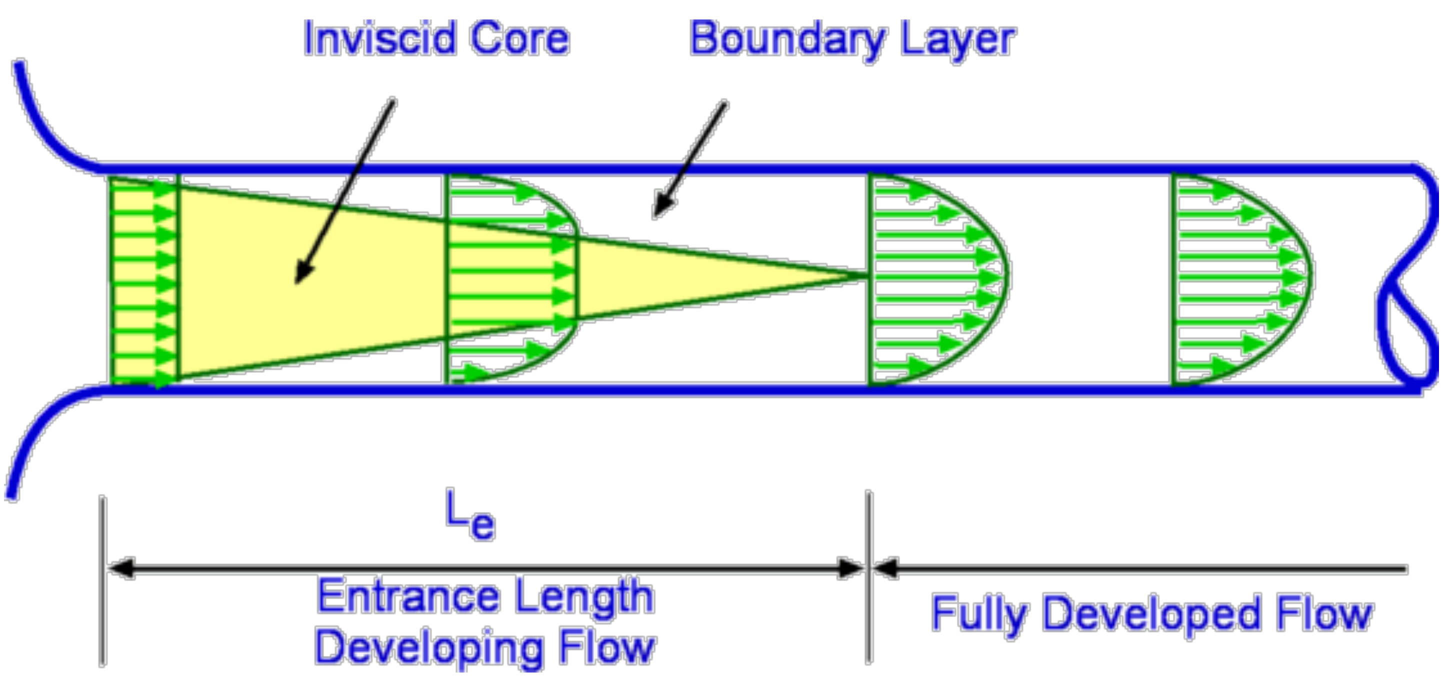
- For turbulent flow equation requires consideration of the roughness (ϵ)

Material	ϵ (μm)	ϵ (μin)
Commercially smooth brass, lead, copper, or plastic pipe	1.52	60
Steel and wrought iron	46	1,800
Galvanized iron or steel	152	6,000
Cast iron	259	10,200

Conduit Friction

- Entrance length:

$$\frac{L_e}{D} = 0.06 \times Re$$



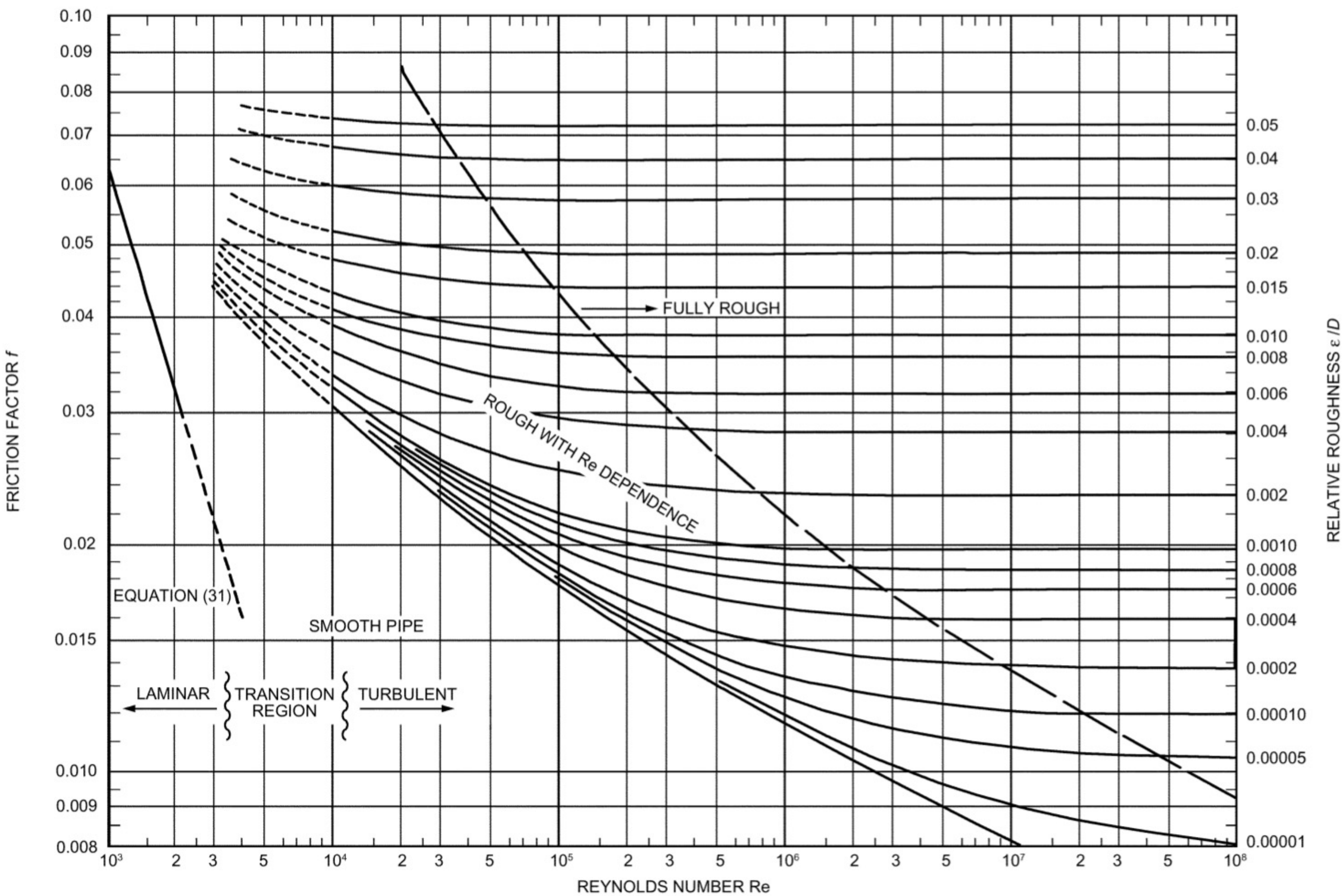
Conduit Friction

- For turbulent flow, friction factor is:

$$\frac{1}{\sqrt{f}} = 1.14 + 2\log(\frac{D}{e})$$

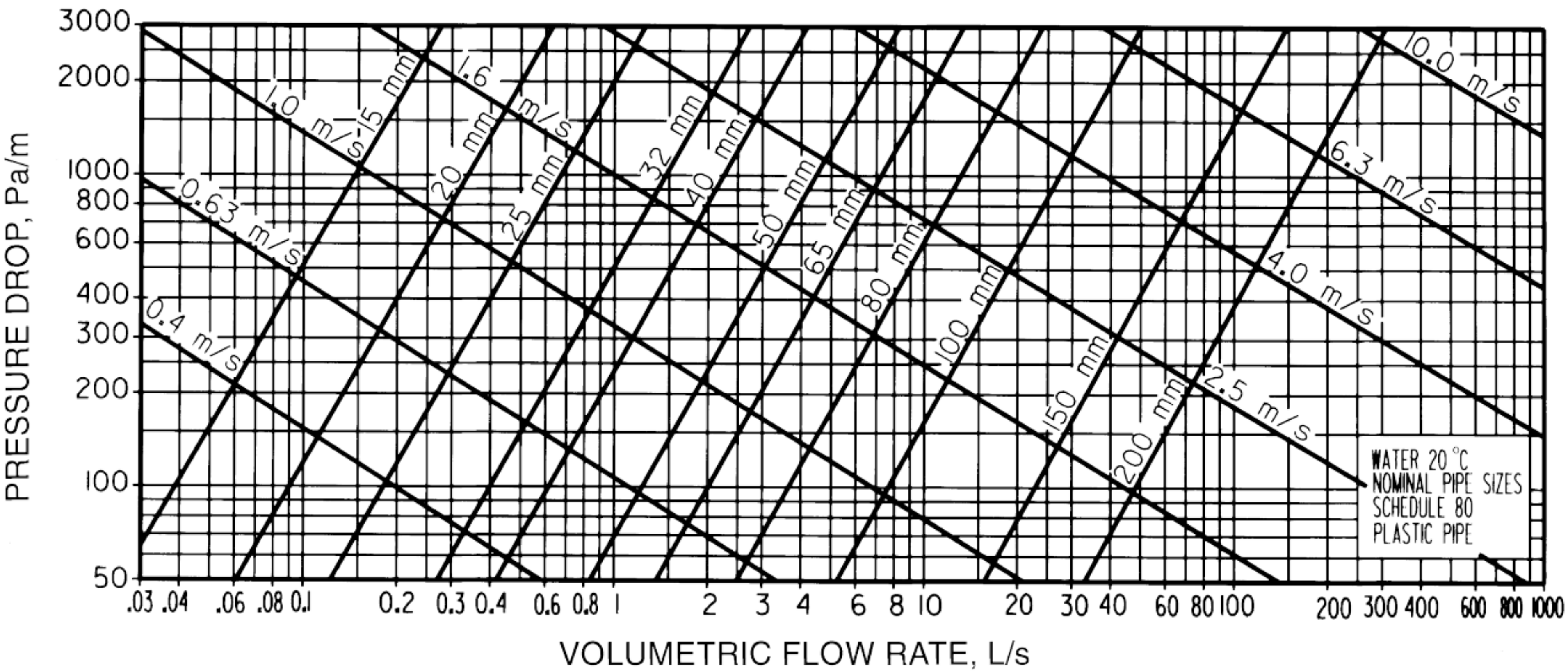
$$f = \frac{1.325}{\left\{\ln[\frac{\epsilon}{3.7D_h} + \frac{5.74}{Re^{0.9}}\right\}^2}$$

Friction Factor



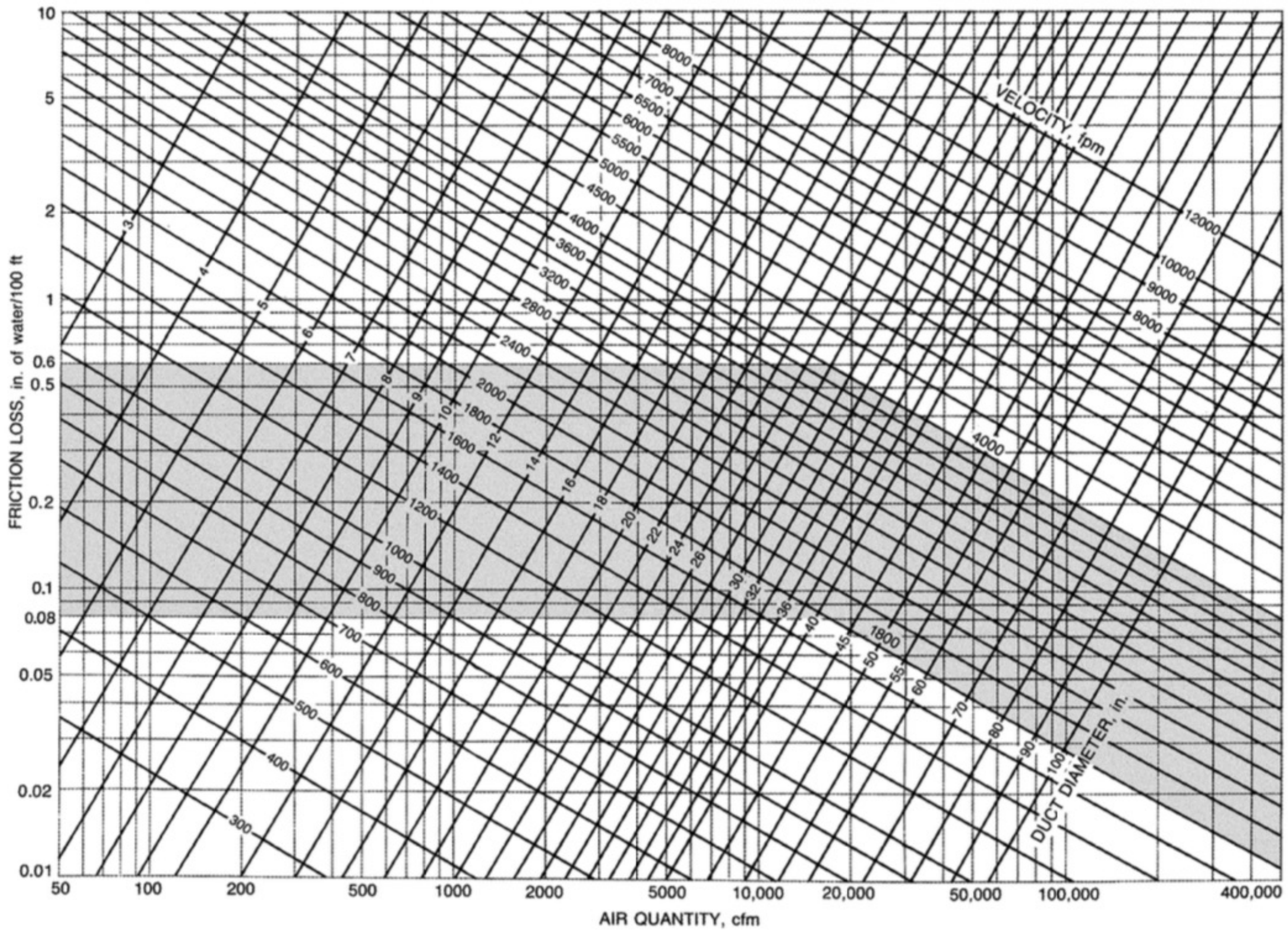
Friction Factor

- We use modified Moody Chart for our air and water calculations



Friction Factor

- We use modified Moody Chart for our air and water calculations



Loss Coefficients

- Besides the conduit friction, there are major losses due to:
  - ❑ Pipe entrance and exit
  - ❑ Sudden expansion or contraction
  - ❑ Bends, elbows, tees, and other fittings
  - ❑ Valves, open or partially closed
  - ❑ Gradual expansions or contractions

Loss Coefficient

- Consider loss coefficient (K) for fittings as:

$$Loss\ of\ section = K\left(\frac{V^2}{2g}\right)$$

Loss Coefficient

- Adding them together, the total losses in the pipe is:

$$H_{Lf} = \left[K + f\left(\frac{L}{D}\right)\right]\left(\frac{V^2}{2g}\right)$$

Loss Coefficient

- Which fitting do you think will have the highest loss coefficient?

Fitting	Geometry	$K = \frac{\Delta P/\rho g}{V^2/2g}$
Entrance	Sharp	0.5
	Well-rounded	0.05
Contraction	Sharp ($D_2/D_1 = 0.5$)	0.38
90° elbow	Miter	1.3
	Short radius	0.90
	Long radius	0.60
	Miter with turning vanes	0.2
Globe valve	Open	10
Angle valve	Open	5
Gate valve	Open	0.19 to 0.22
	75% open	1.10
	50% open	3.6
	25% open	28.8
Any valve	Closed	∞
Tee	Straight-through flow	0.5
	Flow through branch	1.8

Summary

- For an air duct system, how do we estimate the air flow rate?

ASHRAE 62.1

ASHRAE 62.1

ASHRAE

STANDARD

ANSI/ASHRAE Standard 62.1-2022

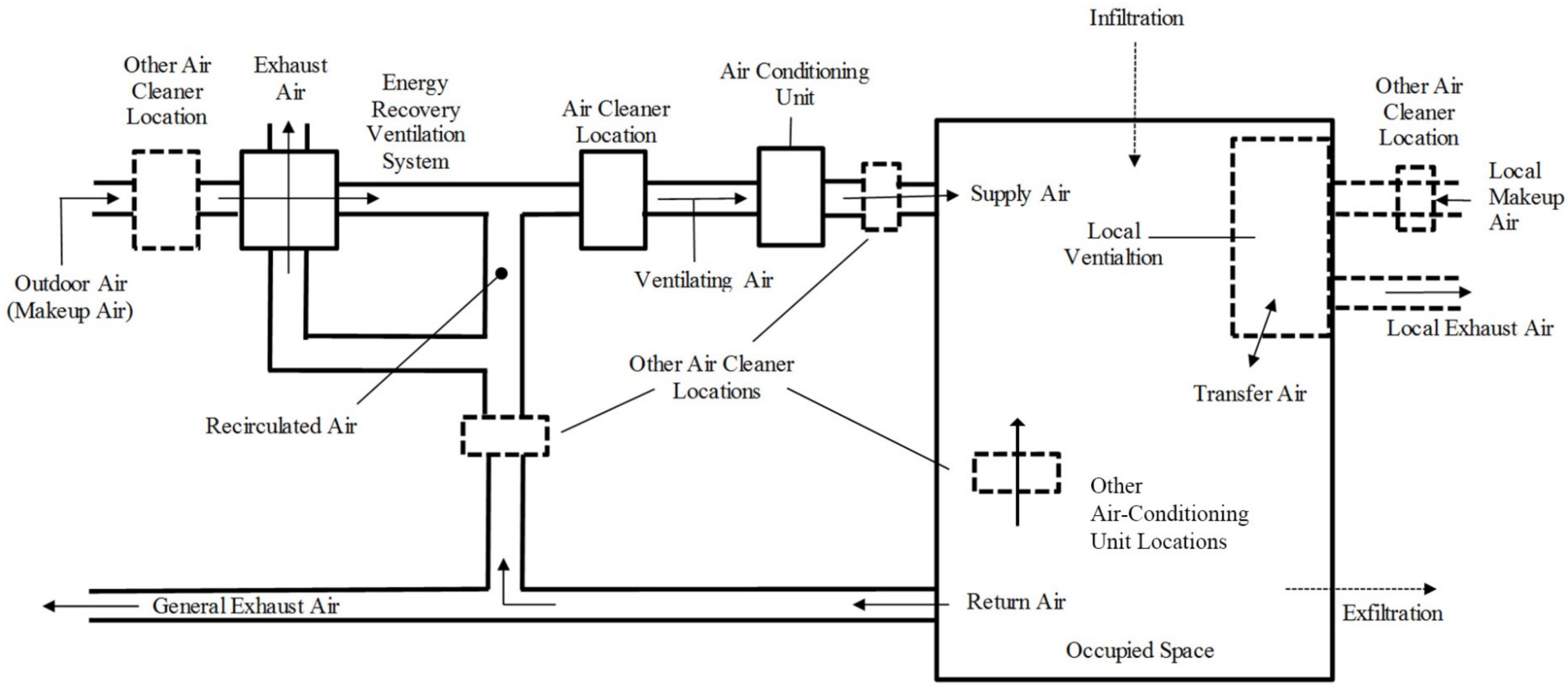
(Supersedes ANSI/ASHRAE Standard 62.1-2019)

Includes ANSI/ASHRAE addenda listed in Appendix Q

Ventilation and Acceptable Indoor Air Quality

ASHRAE 62.1

- Let's look at a common ventilation system and identify major air flows



ASHRAE 62.1

- How to calculate the outdoor air requirement:
  1. First calculate the breathing zone outdoor air flow rate:

$$\dot{V}_{bz} = R_p \times P_z + R_a \times A_z$$

ASHRAE 62.1

- How to calculate the outdoor air requirement:
  2. Then calculate the outdoor air flow rates:

$$\dot{V}_{oz} = \frac{R_p \times P_z + R_a \times A_z}{\mathrm{E_z}}$$

ASHRAE 62.1

- How to calculate the outdoor air requirement:

  3. Design for the worst ventilation if you do not know and round up the numbers to identify the "Design Ventilation"

ASHRAE 62.1

- Let's look at the Standard:

Table 6-1 Minimum Ventilation Rates in Breathing Zone

Occupancy Category	People Outdoor Air Rate R_p cfm/person	People Outdoor Air Rate R_p L/s·person	Area Outdoor Air Rate R_a cfm/ft^2	Area Outdoor Air Rate R_a L/s·m^2	Default Values: Occupant Density #/1000 ft^2 or #/100 m^2	Air Class	OS (6.2.6.1.4)
Animal Facilities							
Animal exam room (veterinary office)	10	5	0.12	0.6	20	2	
Animal imaging (MRI/CT/PET)	10	5	0.18	0.9	20	3	
Animal operating rooms	10	5	0.18	0.9	20	3	
Animal postoperative recovery room	10	5	0.18	0.9	20	3	
Animal preparation rooms	10	5	0.18	0.9	20	3	
Animal procedure room	10	5	0.18	0.9	20	3	
Animal surgery scrub	10	5	0.18	0.9	20	3	
Large-animal holding room	10	5	0.18	0.9	20	3	
Necropsy	10	5	0.18	0.9	20	3	
Small-animal-cage room (static cages)	10	5	0.18	0.9	20	3	
Small-animal-cage room (ventilated cages)	10	5	0.18	0.9	20	3	

ASHRAE 62.1

- Common ventilation effectiveness are calculated as:

Table 6-4 Zone Air Distribution Effectiveness (E_z)

Air Distribution Configuration	E_z
Well-Mixed-Air Distribution Systems	
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is less than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is equal to or greater than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	1.0
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply outlet located more than half the length of the space from the exhaust, return, or both	0.8
Makeup supply outlet located less than half the length of the space from the exhaust, return, or both	0.5

ASHRAE 62.1

- Do you see any information about the healthcare outdoor air requirements in ASHRAE 62.1?

ASHRAE 62.1

STANDARD

ANSI/ASHRAE/ASHE Standard 170-2021
(Supersedes ANSI/ASHRAE/ASHE Standard 170-2017)
Includes ANSI/ASHRAE/ASHE addenda listed in Appendix F

Ventilation of Health Care Facilities

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the ASHE Board of Directors, and the American National Standards Institute.

https://ashrae.iwrapper.com/ViewOnline/Standard_170-2017_(86529)

CLASS ACTIVITY

Class Activity

- Find the required outdoor air flow rate and for a university lecture hall (fixed seat) that has a maximum occupancy of 180 people, and the floor has an area of 1,500 ft^2. Assume the supply and returns are in the ceiling.

Class Activity

- Solution (see Table 6-1):

Table 6-1 Minimum Ventilation Rates in Breathing Zone

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values Occupant Density	Air Class	OS (6.2.6.1.4)
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2	#/1000 ft^2 or #/100 m^2		
Educational Facilities							
Art classroom	10	5	0.18	0.9	20	2	
Classrooms (ages 5 to 8)	10	5	0.12	0.6	25	1	
Classrooms (age 9 plus)	10	5	0.12	0.6	35	1	
Computer lab	10	5	0.12	0.6	25	1	
Daycare sickroom	10	5	0.18	0.9	25	3	
Daycare (through age 4)	10	5	0.18	0.9	25	2	
Lecture classroom	7.5	3.8	0.06	0.3	65	1	✓
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	150	1	✓

Class Activity

- Solution:
  - In this configuration the ventilation effectiveness depends on the cooling or heating mode
  - We usually consider the worst condition (e.g., 0.7 and 0.8)

Class Activity

- Solution:

$$\dot{V}_{bz} = R_p \times P_z + R_a \times A_z$$

$$\dot{V}_{bz} = (7.5)(180) + (0.06)(1{,}500) = 1{,}440\ cfm$$

$$\dot{V}_{oz} = \frac{\dot{V}_{bz}}{E_z} = \frac{1{,}440\ cfm}{0.8} = 1{,}800\ cfm$$

Class Activity

- What do we do if occupancy is not given?

Class Activity

- Solution:

Table 6-1 Minimum Ventilation Rates in Breathing Zone

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values Occupant Density	Air Class	OS (6.2.6.1.4)
	cfm/ person	L/s· person	cfm/ft^2	L/s·m^2	#/1000 ft^2 or #/100 m^2		
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Art classroom	10	5	0.18	0.9	20	2	
Classrooms (ages 5 to 8)	10	5	0.12	0.6	25	1	
Classrooms (age 9 plus)	10	5	0.12	0.6	35	1	
Computer lab	10	5	0.12	0.6	25	1	
Daycare sickroom	10	5	0.18	0.9	25	3	
Daycare (through age 4)	10	5	0.18	0.9	25	2	
Lecture classroom	7.5	3.8	0.06	0.3	65	1	✓
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	150	1	✓

Class Activity

- Solution:
  - 8 cfm/person based on an occupancy of 150 person per 1,000 ft^2
  - The outdoor air delivery is:

$$\dot{V}_{bz} = R_c P_c$$

$$\dot{V}_{bz} = (7.5)\left(\frac{150\times1{,}500}{1{,}000}\right) = 1{,}687.5\ cfm$$

$$\dot{V}_{oz} = \frac{\dot{V}_{bz}}{E_z} = \frac{1{,}6875.5}{0.8} = 2{,}109.375\ cfm$$

Air Requirement

- How much is the total airflow requirements? Can we use ASHRAE 62.1 to calculate the entire airflow requirement for a building and design the AHUs?

Air Requirement

- Let's look at Assignment 1:

VENTILATION SCHEDULE

ROOM NO.	ROOM NAME	PURPOSE	FLOOR AREA SQ. FT.	MECHANICAL VENTILATION: ORDINANCE REQUIREMENTS SUPPLY AIR CFM	MECHANICAL VENTILATION: ORDINANCE REQUIREMENTS EXHAUST AIR CFM	MECHANICAL VENTILATION: PLAN REQUIREMENTS SUPPLY AIR CFM	MECHANICAL VENTILATION: PLAN REQUIREMENTS EXHAUST AIR CFM	FAN TAG: SUPPLY FAN	FAN TAG: EXH. FAN	REMARKS	HEAT LOSS: ROOM BTU/HR	HEAT LOSS: OUTDOOR AIR BTU/HR
101	CORRIDOR	LOBBY	2220	–	–	5000	5000	RTU–1	RTU–1	BB–2.FPB–4,5	120,000	0
102	STAIR	STAIRS	252	N.R.	N.R.	0	0	RTU–1	RTU–1	–	6000	0
103	MEN	TOILET ROOM	280	N.R.	560	450	600	RTU–1	TE–1	–	15000	0
104	OFFICE SUITE	OFFICE	290	175	90	1880	1880	RTU–1	RTU–1	–	8120	53605
104A	VESTIBULE	VESTIBULE	100	N.R.	N.R.	0	0	RTU–1	RTU–1	–	0	0
104B	VESTIBULE	VESTIBULE	225	N.R.	N.R.	100	0	RTU–1	RTU–1	–	0	0
104C	STUDENT COMMON AREA	OFFICE	350	210	105	560	0	RTU–1	EXIST.	–	9800	15965
105	OFFICE	OFFICE	150	90	45	540	540	RTU–1	RTU–1	–	4200	15395
106	ANALYTICAL CHARACTERIZATION LAB	LABORATORY	150	180	180	680	600	RTU–1	RTU–1	–	4200	19390
107	PROCESSING LAB	LABORATORY	850	1020	1020	2800	3250	RTU–1	EF–3	–	23800	79835
108	REACTION ENGINEERING LAB	LABORATORY	790	950	950	5010	5400	RTU–1	EXIST.	–	22120	142845
108A	ELECTRICAL ROOM	ELECTRICAL ROOM	52	N.R.	N.R.	0	0	RTU–1	RTU–1	–	1455	0
109	POLYMER RHEOLOGY LAB	LABORATORY	555	665	665	1600	1800	RTU–1	EF–3	–	15540	45620
110A	FORCED RAYLEIGH SCATTER LAB	LABORATORY	150	180	180	200	200	RTU–1	RTU–1	–	4200	5700
112	CORRIDOR	CORRIDOR	514	N.R.	N.R.	1100	675	RTU–1	RTU–1	–	17500	0
113	CLASSROOM	LECTURE HALL	2723	4080	4080	7500	7500	RTU–1	RTU–1	–	80000	116328
113A	EXISTING STORAGE	STORAGE	30	N.R.	N.R.	0	0	RTU–1	RTU–1	–	0	0
114	CORRIDOR	CORRIDOR	452	N.R.	N.R.	800	675	RTU–1	RTU–1	–	17500	0
115	CLASSROOM	CLASSROOM	925	1400	700	3180	3180	RTU–1	RTU–1	–	41500	37065
116	CLASSROOM	CLASSROOM	925	1400	700	3120	3120	RTU–1	RTU–1	–	41400	14170
117	CLASSROOM	CLASSROOM	845	1300	650	2490	2490	RTU–1	RTU–1	–	12650	4330
118	T/C CLOSET	T/C CLOSET	49	N.R.	N.R.	400	400	RTU–1	RTU–1	–	0	0
119	CLASSROOM	CLASSROOM	625	950	475	2200	2200	RTU–1	RTU–1	–	44300	37065
119A	STORAGE	STORAGE	105	N.R.	N.R.	0	0	RTU–1	RTU–1	–	0	0
120	VESTIBULE	VESTIBULE	235	N.R.	N.R.	100	100	RTU–1	RTU–1	–	0	0
120A	OFFICE	OFFICE	195	120	60	130	130	RTU–1	RTU–1	–	8300	4320
120B	CORRIDOR	CORRIDOR	95	N.R.	N.R.	0	0	RTU–1	RTU–1	–	15450	5274
125	WOMEN	TOILET ROOM	280	0	560	450	600	RTU–1	TE–2	–	14000	0
127	STAIR	STAIRS	252	N.R.	N.R.	0	0	RTU–1	RTU–1	–	0	0
			11092	12720	11040	40290	40340				TOTAL = 527035	TOTAL = 635787

TOTAL = 1162822

RELEVANT TOOLS

Relevant Tools

- There are relevant tools:

About LEED Credentials Education Membership Store Resources Directory

Calculators

Minimum Indoor Air Quality Performance Calculator

LEED version: v4

DOWNLOAD

Format: Excel Doc

The Minimum Indoor Air Quality Performance Calculator can be used for projects using ASHRAE 62.1 to comply with LEED BD+C, ID+C and O+M EQ Prerequisite Minimum Indoor Air Quality Performance, EQ Credit Increased Ventilation, and EQ Credit Enhanced Indoor Air Quality Strategies, Option 2, Strategy B: Increased Ventilation, as well as LEED Homes and Multifamily Midrise EQ Prerequisite Ventilation. The calculator accommodates all ventilation types (multiple zone, single-zone, 100% outside air) in one spreadsheet. Assumptions for occupancy categories are from ASHRAE 62.1-2010 (for LEED v4 projects) and ASHRAE 62.1-2007 (for LEED 2009 projects).

Updates

- 11/14/2019 - v04 - Updated to include LEED v4.1 option
- 6/3/2016 - v03
  1. Fixed bug with default values for zone population in the single zone sheet
  2. Updated Table 6-3 calculation for Ev in the multiple zone sheet to not exceed 1.0 when Max Zp<0.15
  3. In multiple zone sheet, changed Ep from user entry to calculated value.
  4. Added column for Zone outdoor airflow provided to the 100% OA and corresponding column in the summary tab (zone outdoor airflow provided meets or exceeds Voz for all zones).
  5. Note added to Are you using default value for zone population to clarify default values should only be used if expected occupancy is unknown.
  6. Modified rounding and decimals displayed
  7. Fixed bug in summary sheet so that all systems are always displayed.

https://www.usgbc.org/resources/minimum-indoor-air-quality-performance-calculator

Relevant Tools

- There are relevant tools:

‹ NIST

MULTIZONE MODELING

Quick Indoor CO2 (QICO2)

An Indoor Carbon Dioxide Metric Analysis Tool

link to documentation of this tool.

Building Type

(•) Commercial/Institutional ( ) Residential

Model Type

(•) Predefined ( ) User-Defined

Predefined Commercial Buildings (from ASHRAE Standard 62.1-2019)

Classroom (5-8 y)

Outdoor CO2 Concentration
400 ppm

Ceiling Height
3 m

62.1 Ventilation Rate per Person
5 L/s

62.1 Ventilation Rate per Floor Area
0.6 L/s·m²

Occupant Density
25 #/100 m²

Primary Ventilation Rate per Person
7.4 L/s

Time to Metric
2 h

Alternate Ventilation Rate per Person:
10 sL/s

Predefined Occupants

Number of Occupants	Sex	Mass (kg)	Age Group	Activity Level (met)
12	M	23	3 to 9	2
12	F	23	3 to 9	2
1	M	85	30 to 59	3

Copy to User-Defined Model

Get Results

https://pages.nist.gov/CONTAM-apps/webapps/CO2Tool/#/

Relevant Tools

- There are relevant tools:

READ THIS FIRST

To use this spreadsheet, identify the zones served by the system being designed and list them in row 11. Then select the space type using the pull down menus in row 12. For each zone, enter the values in all yellow shaded cells, plus the total number of occupants expected to be served by the system in cell C36.

The values used for Vpz, Vdz and Vdzm depend on whether one is designing a CAV or VAV system. Notes in **bold text** are included below that explain these distinctions.

NOTE: Various sums and formulas in column C (in boxes) are based on the individual zone data entered from column C through column Z. If the system, has more than 24 zones, then the sums and formulas in column C need to be modified to include all the zones.

RESULTS		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**1611**
	Percent outdoor air intake, Vot/Vps	**64%**
Ev	**System ventilation efficiency**	**0.87**

ZONE LEVEL

	Zones served by system	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**							
	Space type (select from pull-down list)	Lobbies/pre	Office spac	Classrooms	Conference	Office spac	Office spac	Office spac	Office spac	Office spac	Office spac	Office sp
Az	Floor area of zone, ft2	3340	4000	2500								
Pz	Zone population, largest # of people expected to occupy zone	20	32	70								
Rp	People outdoor air rate from Table 6.1, cfm/person	7.5	5	10	5	5	5	5	5	5	5	
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.06	0.06	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.0
Pz*Rp		150	160	700	0	0	0	0	0	0	0	
Az*Ra		200.4	240	300	0	0	0	0	0	0	0	
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	350.4	400	1000	0	0	0	0	0	0	0	
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design value.**	650	850	1000								
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	2600	3400	4000								
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	2600	3400	4000								
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.13	0.12	0.25	NA	NA	NA	NA	NA	NA	NA	N
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.25	0.25	0.25	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.80	0.80	0.80								
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00								
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.85	0.85	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.25	0.25	0.25	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	80
D	Occupant diversity, ratio of system peak occupancy to sum of	0.66

https://www.ashrae.org/File%20Library/Technical%20Resources/Standards%20and%20Guidelines/Standards%20Intepretations/VRP-Excel-Spreadsheet.xls