ME444 ENGINEERING PIPING SYSTEM DESIGN

CHAPTER 13 : COMPRESSED AIR PIPING

CONTENT

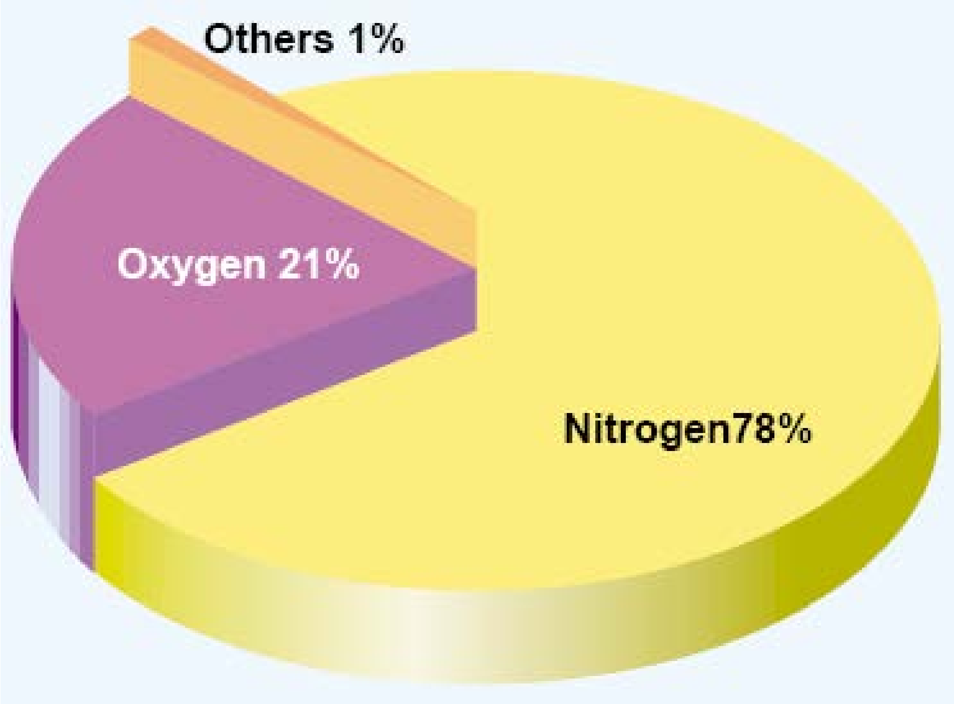
1. INTRODUCTION

COMPRESSED AIR SERVES MANY PURPOSES

- **DELIVER MECHANICAL ENERGY (PNEUMATIC SYSTEM)**
- **PROCESS AIR SUPPLY (MIXING, AGITATION)**
- **DRYING AND CLEANING (NOT RECOMMENDED)**

ETC.

AIR



C_p = 1.01 kJ/kg.K

C_v = 0.72 kJ/kg.K

k = C_p/C_v

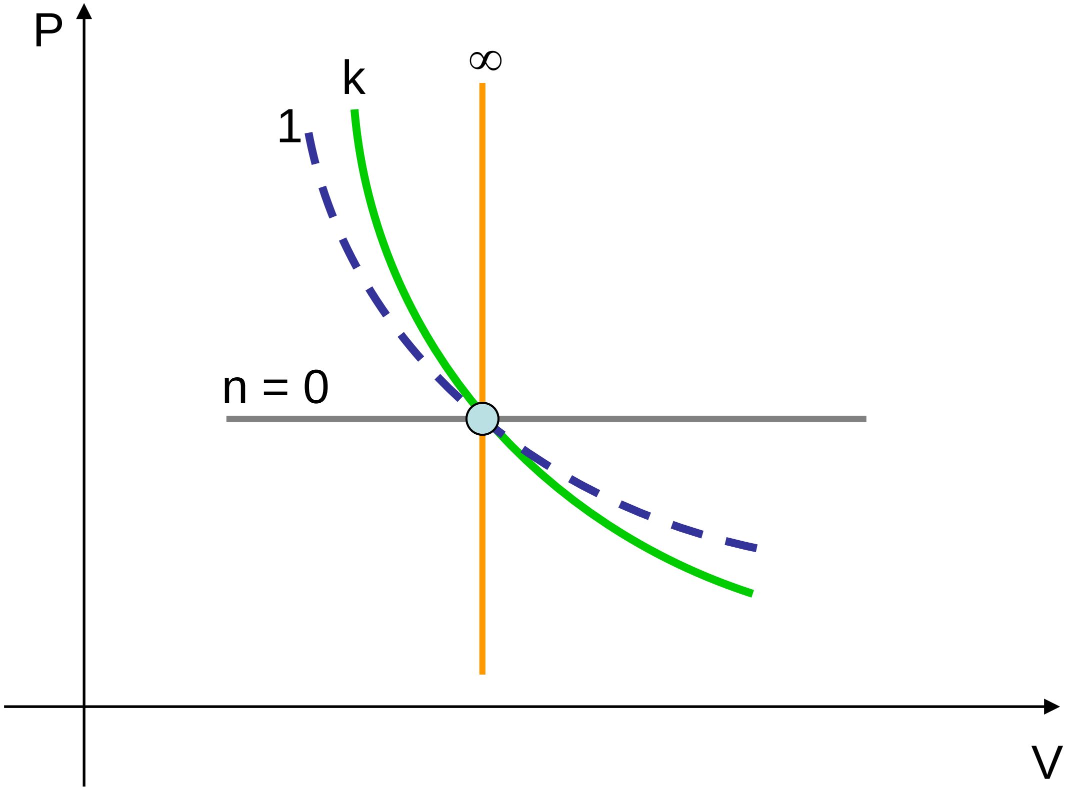
= 1.4

AT STP (0 °C and 101.325 kPa), dry air has a density of ρSTP = 1.293 g/L

COMPRESSION CYCLES

PV^n = Constant

n = 0 ISOBARIC
n = 1 ISOTHERMAL
n = k ISENTROPIC
n = ∞ ISOCHORIC

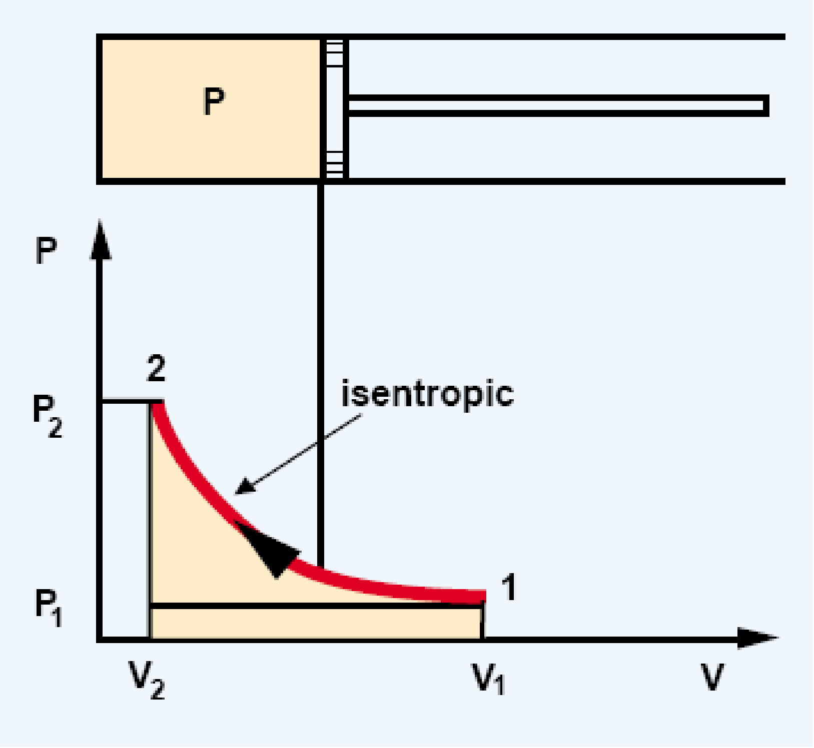


ISENTROPIC COMPRESSION PROCESS

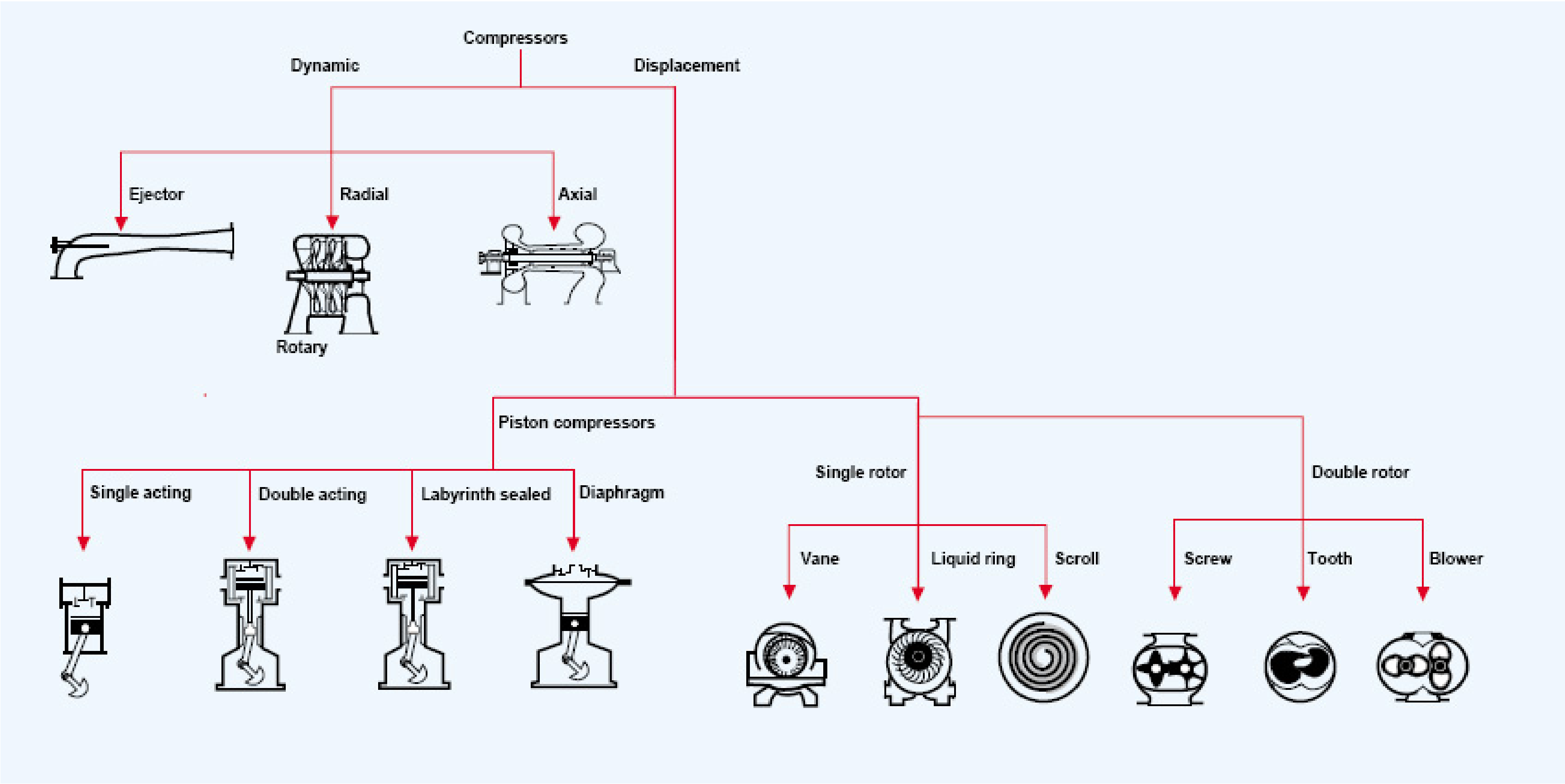
Fully insulated cylinder
No heat exchange with the surroundings.
Constant entropy

$$\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{\kappa} \Rightarrow \frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{\kappa}{\kappa-1}}$$

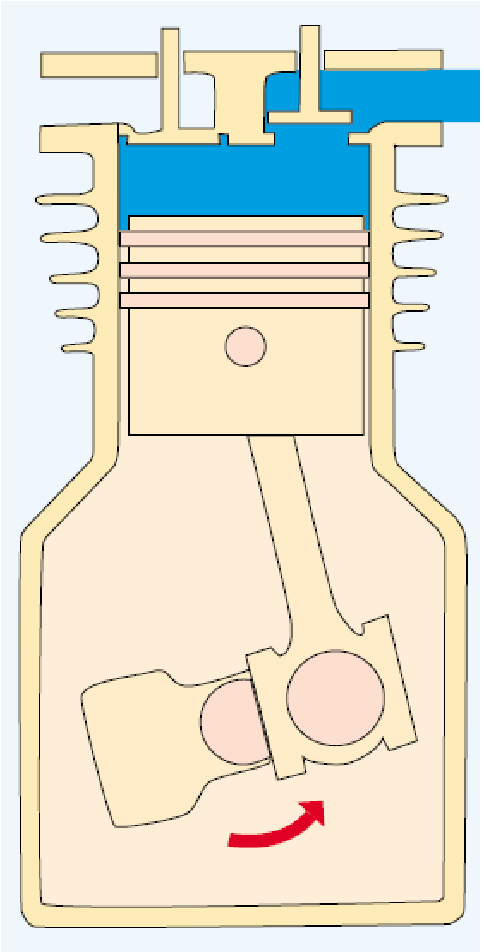
p = absolute pressure (Pa)
V = volume (m^3)
T = absolute temperature (K)
$\kappa = \frac{c_p}{c_v}$

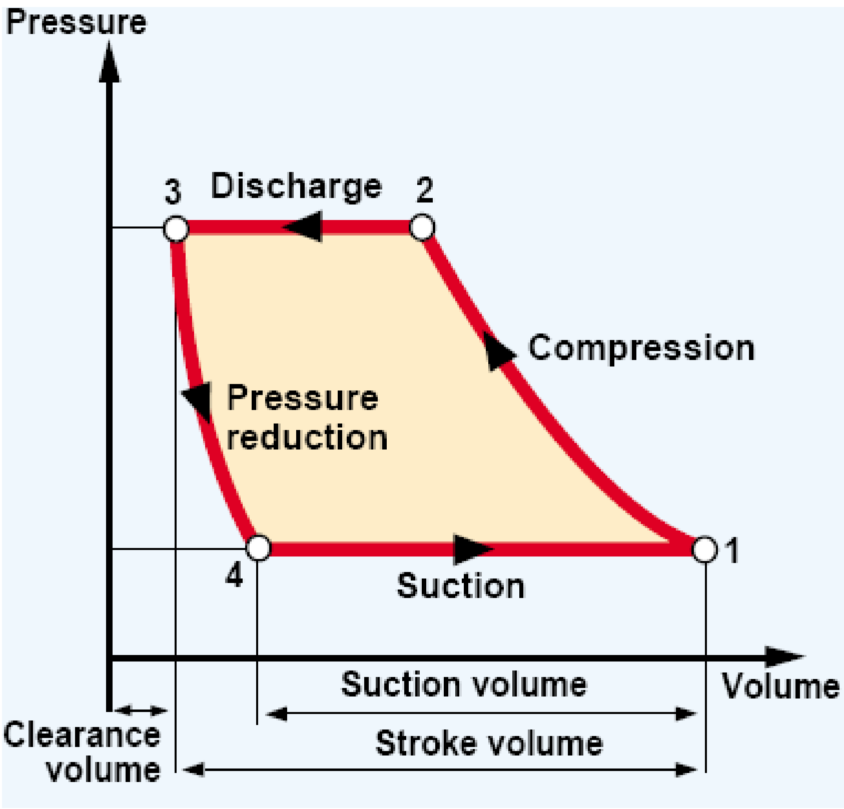


2. COMPONENTS

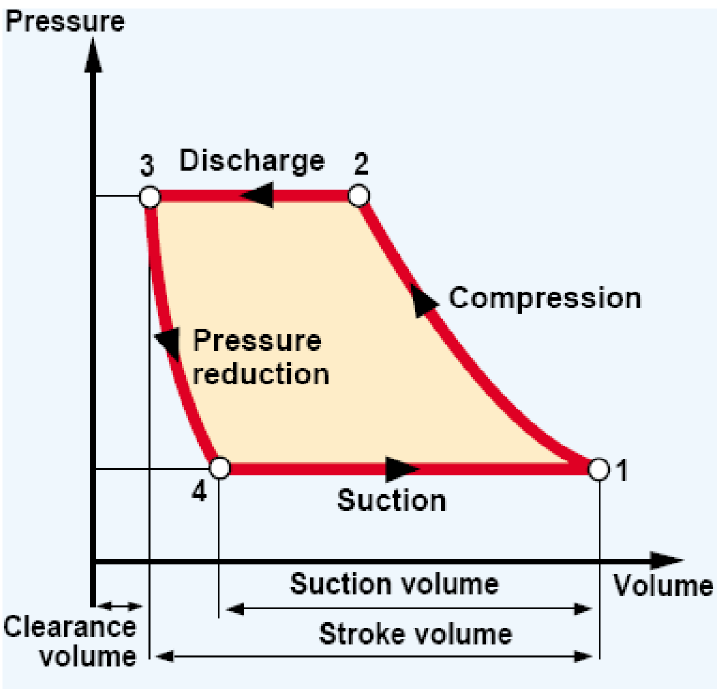


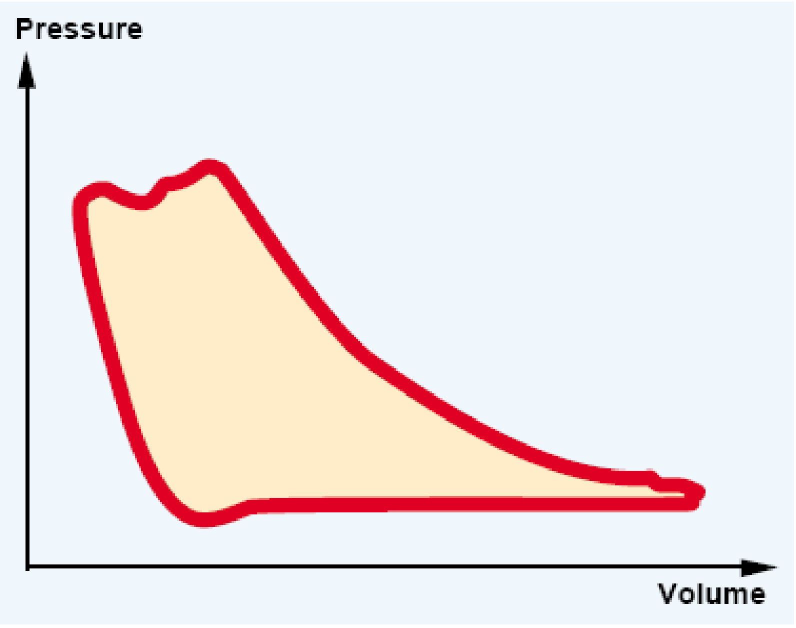
DISPLACEMENT COMPRESSOR



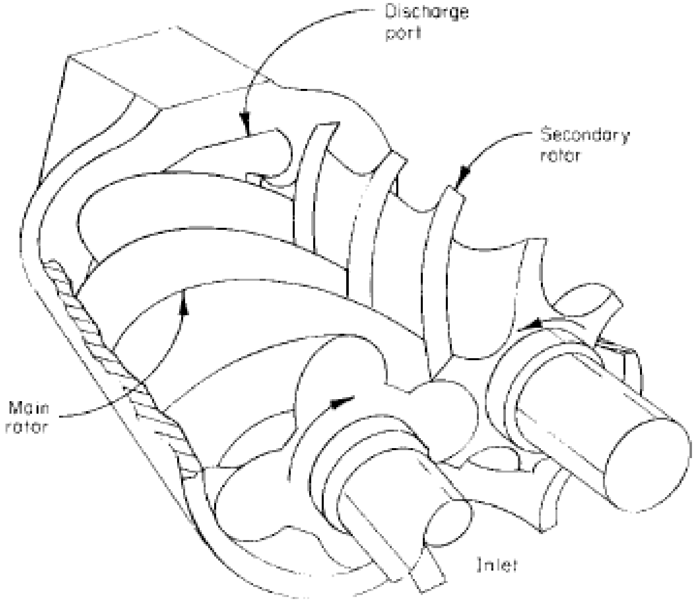


ACTUAL COMPRESSION CYCLE

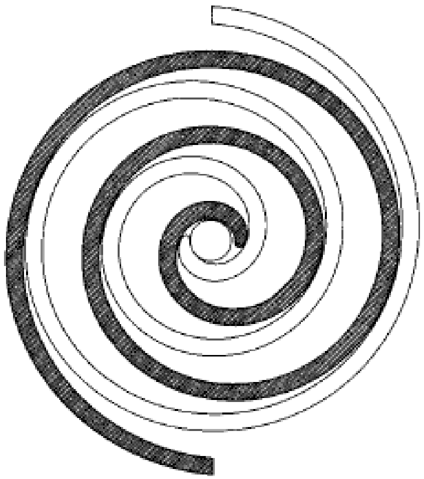




ROTARY DISPLACEMENT COMPRESSORS

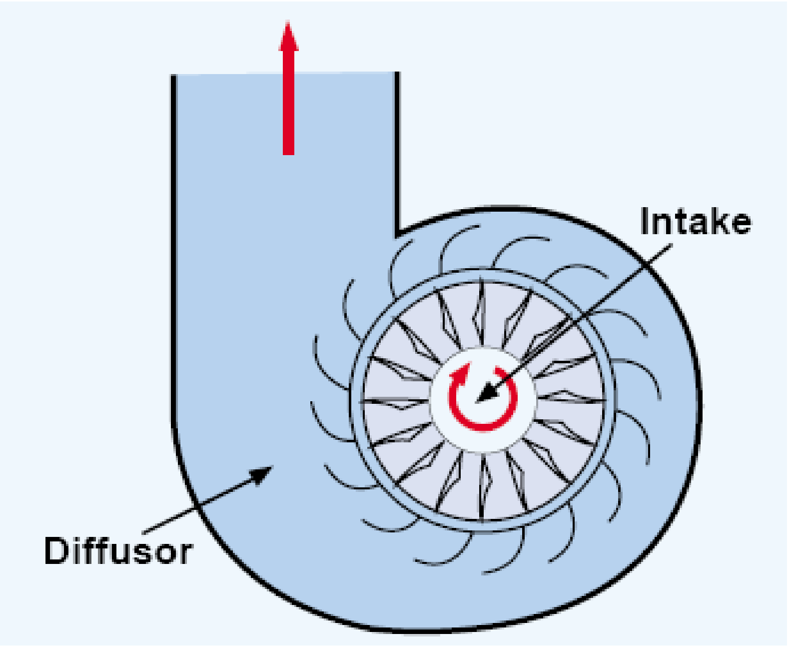


SCREW

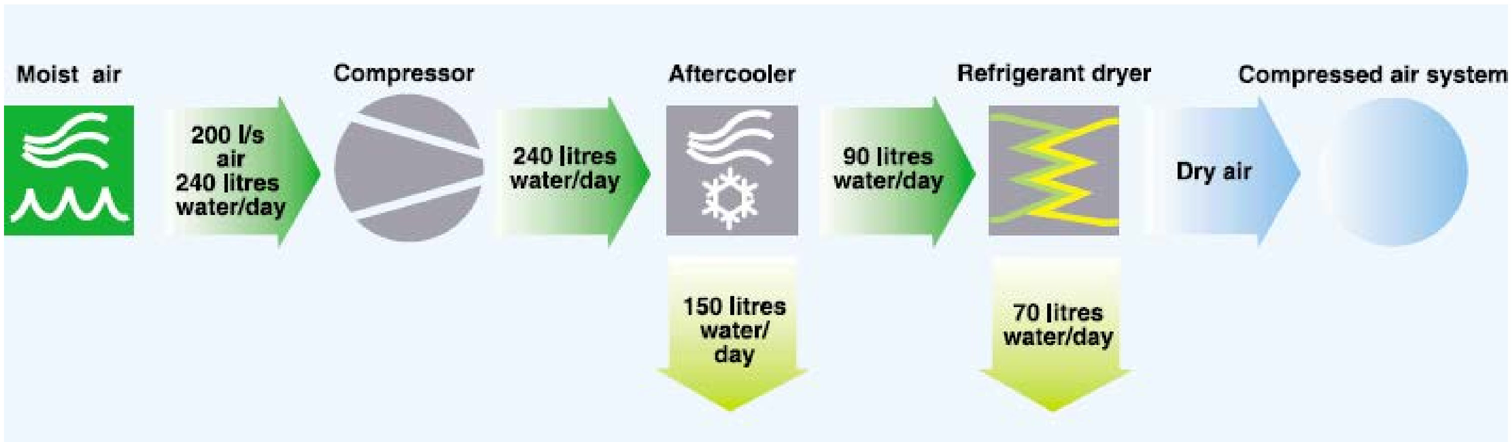


SCROLL

DYNAMICS COMPRESSORS

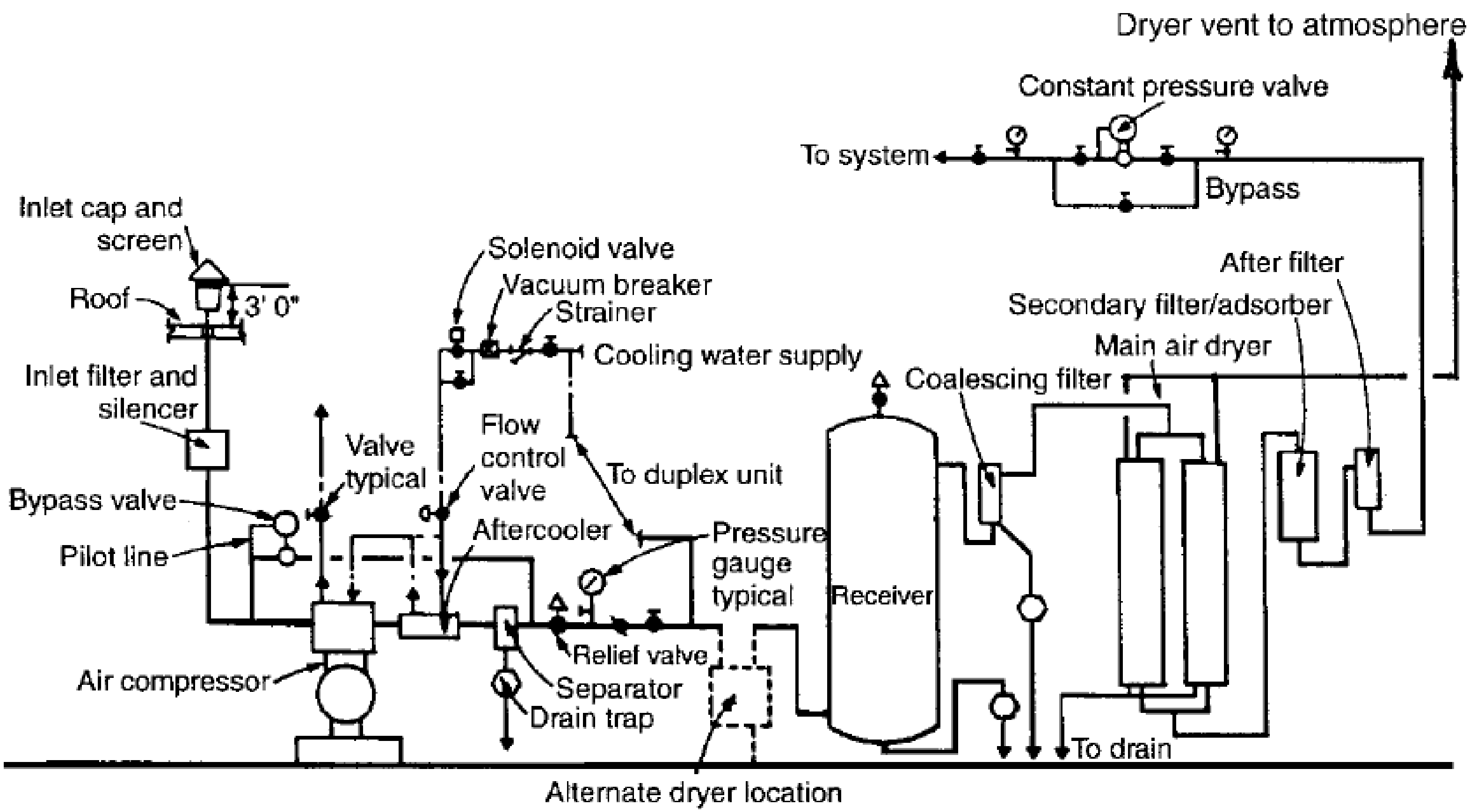


ACCESSORIES

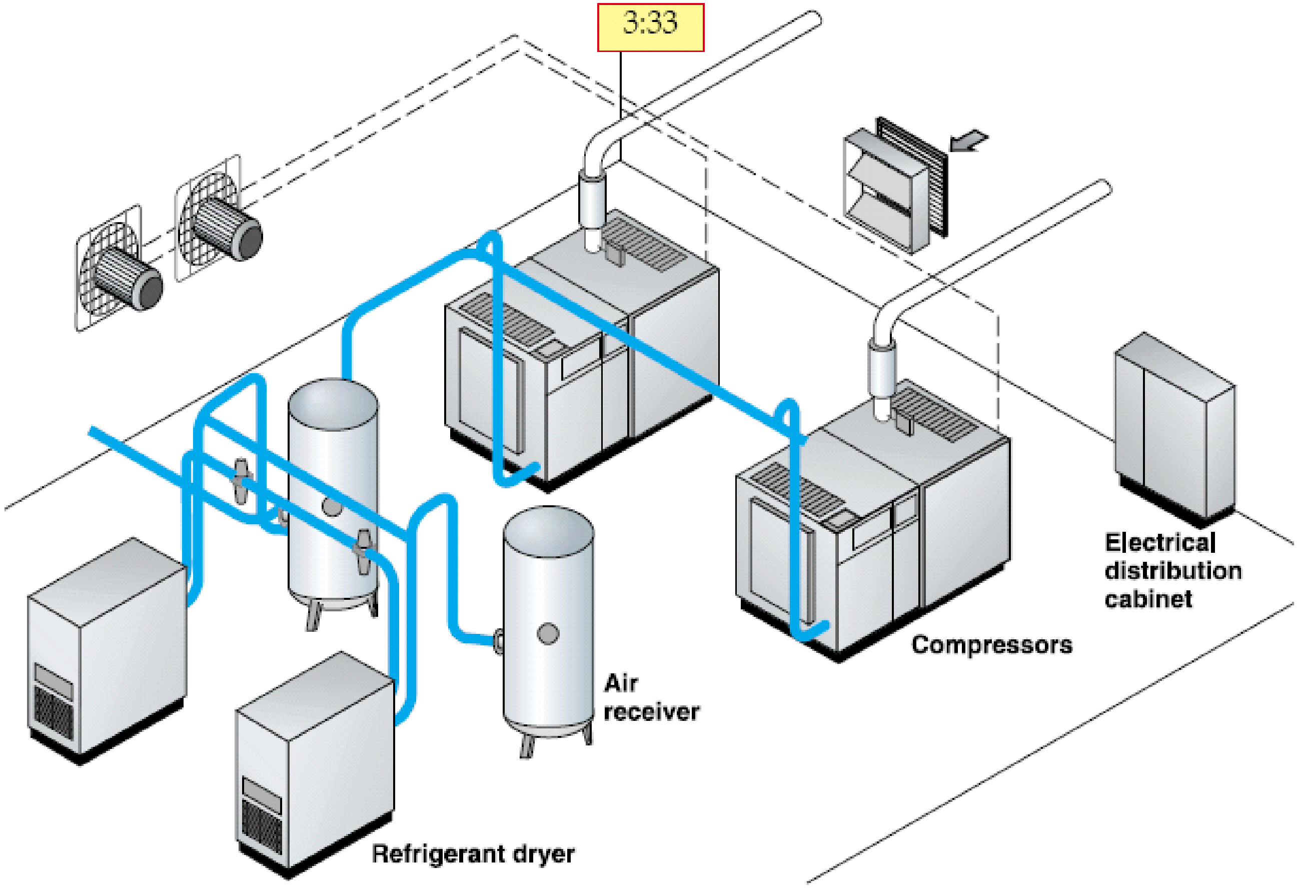


FILTERS
DRYERS
SILENCERS
REGULATORS
VALVES

TYPICAL AIR COMPRESSOR ASSEMBLY



COMPRESSOR ROOM



AUTOMATIC DRAIN

PNUMATIC EQUIPMENTS

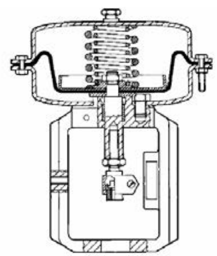












3. PIPING SYSTEM

General practice

- Tap from top of main pipe
- Slope toward automatic drain
- V < 6 m/s
- Use ring loop for large system
- Consider 5% minimum leakage

PIPING SYSTEM DESIGN SEQUENCES

1. Locate and identify each process, work station, or piece of equipment using compressed air. This is known as the *total connected load.* These elements

2. Determine volume of air used at each location.

3. Determine pressure range required at each location.

4. Determine conditioning requirements for each item, such as allowable moisture content, particulate size, and oil content.

5. Establish how much time the individual tool or process will be in actual use for a specific period of time. This is referred to as the *duty cycle.* This information will help determine the simultaneous-use factor by eliminating some locations during periods of use at other locations.

PIPING SYSTEM DESIGN SEQUENCES

6. Establish the maximum number of locations that may be used simultaneously on each branch, main, and for the project as a whole. This is known as the *use factor.*

7. Establish the extent of allowable leakage (2%-5% for good system).

8. Establish any allowance for future expansion.

9. Make a preliminary piping layout, and assign preliminary pressure drop.

10. Select the air compressor type, conditioning equipment, equipment and air inlet locations making sure that consistent scfm (scmm) or acfm (acmm) is used for both the system and compressor capacity rating.

11. Produce a final piping layout, and size the piping network.

COMPRESSOR SELECTION

Flow rate

Survey the requirement
Consider use factor
Account for leakage
Apply margin of safety

Pressure

Description	Pressure drop bar(e)
End user	6
Final filter	0.1–0.5
Pipe system	0.2
Dust filter	0.1–0.5
Dryer	0.1
Compressor's regulation range	0.5
Compressor's max working pressure	7.0–7.8

ABOUT AIR PRESSURE AND FLOW RATE

ACFM – ACTUAL MEASUREMENT OF COMPRESSED AIR
SCFM – EQUIVALENT TO FREE AIR AT 0 PSIG

100 ACFM @ 100 PSIG = 100 X (100+14.7) / 14.7
= 780 SCFM

1 psig X 7 = kPa.
1 cfm X 0.03 = m3 / min.

FAD = Free Air Deliverly

AIR REQUIREMENT

Machine type and size	Air requirement max. l/s
Drilling machines, Ø = bit diameter (mm)	
Small Ø < 6.5	**6.0**
Medium 6.5 < Ø = < 10	**7.5**
Large 10 < Ø < 16	**16.5**
Thread cutters	**6**
Screwdriver, d = screw size	
Small d < M6	**5.5**
Medium M6 < d < M8	**7.5**
Impact wrench, d = bolt size	
Small d < M10	**5.0**
Medium M10 < d < M20	**7.5**
Large d ≥ M20	**22.0**

AIR REQUIREMENT

Filing machine	**7.5**
Polishers/Die grinders, e = power (kW)	
Small e < 0.5	**8.0**
Large e > 0.5	**16.5**
Grinders, e = power (kW)	
Small 0.4 < e < 1.0	**20.0**
Medium 1,0 < e < 2	**40.0**
Large e > 2	**60.0**
Chipping hammers	
Light	**6.0**
Heavy	**13.5**
Air hoists t = lifting tonnage	
t < 1 tonne	**35**
t > 1 tonne	**45**

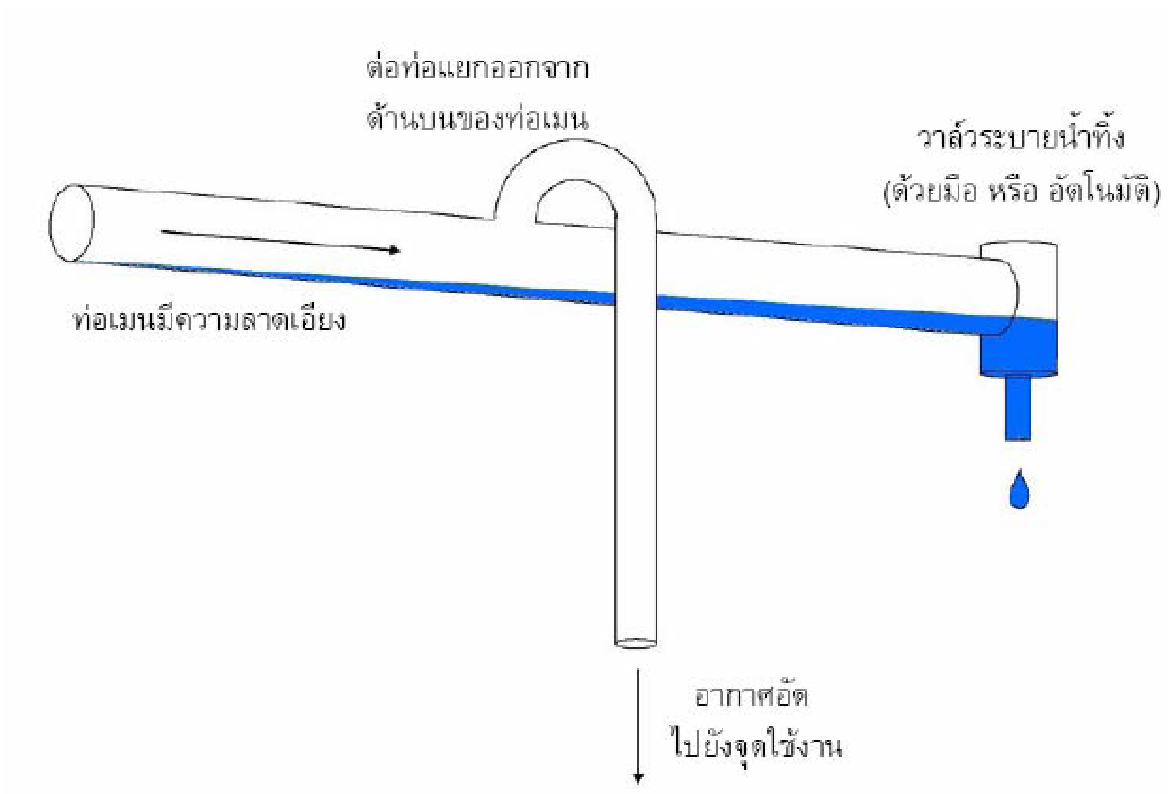
AIR REQUIREMENT

Scaler	**5.0**
Cleaning nozzle	**6.0**
Nutrunner, d = bolt size d ≤ M8 d ≥ M10	 **9** **19**

LABORATORY OUTLET USE FACTOR

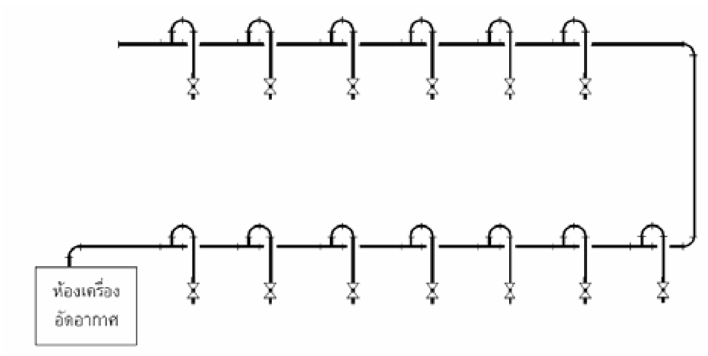
No. of outlets	Percent use factor
1–2	100
3–5	80
6–10	66
11–20	40
21–50	30
Over 50	20

SLOPE DOWN AND TAP FROM TOP



LAYOUT

A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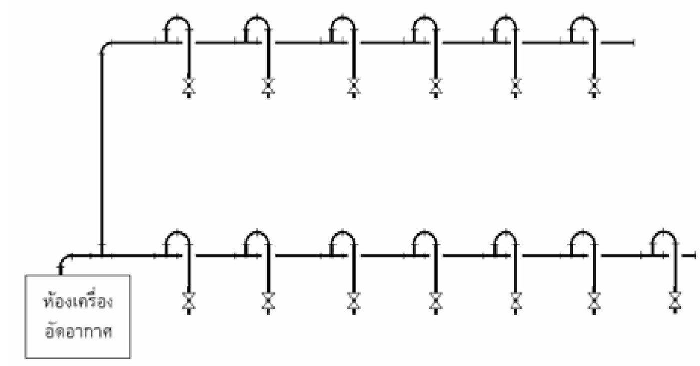
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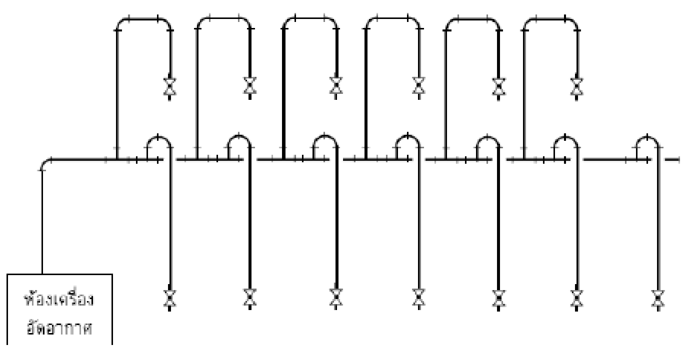
C

B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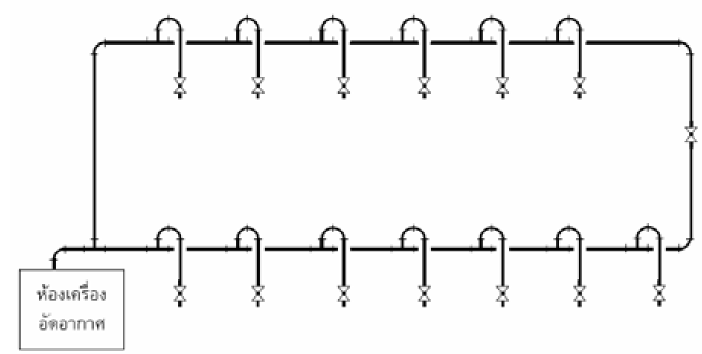
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D

4. PIPING SIZING

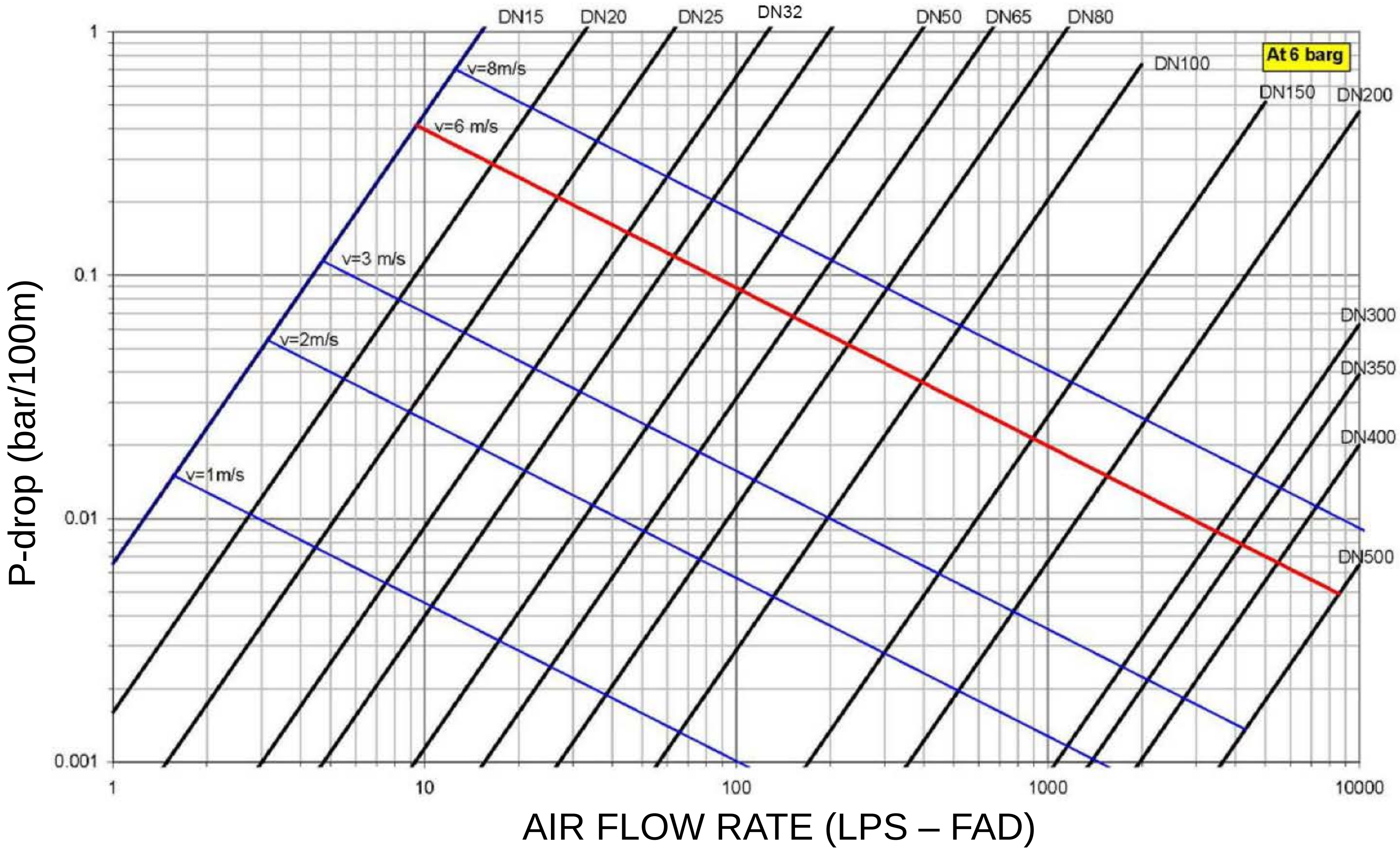
- ESTABLISH THE PIPE LAYOUT
- DETERMINE THE LONGEST RUN
- DETERMINE THE EQUIVALENT LENGTH
- (150% OF THE ACTUAL LENGTH IS PRACTICAL)
- ALLOW PRESSURE TO DROP UP TO 10%
- VELOCITY OF AIR SHOULD BE LESS THAN 6 M/S

PRESSURE DROP

$$\Delta p = 450 \frac{Q_c^{1.85} \times l}{d^5 \times p}$$

Q_c	in litre per second (FAD)
l	in metre
d	in mm.
p	in bar (absolute)

PRESSURE DROP CHART



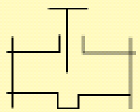
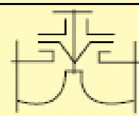
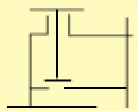
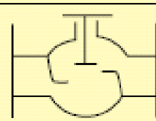
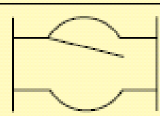
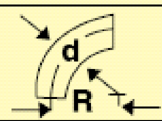
PRESSURE DROP AND PIPE SIZE

EXAMPLE

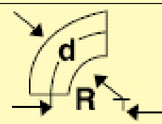
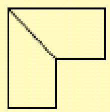
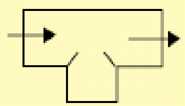
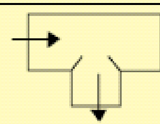
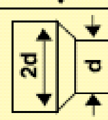
Kw@ 6kW/m/m	Flowrate (LPS)	Pressure (Bar-g)	Pipe size (inch)	DP (bar/100m)	Velocity (m/s)
1.8	5	8	0.5	0.0998	2.834
3.6	10	8	0.75	0.0881	3.230
5.4	15	8	1	0.0558	2.989
9.0	25	8	1.25	0.0392	2.964
14.4	40	8	1.50	0.0402	3.384
28.8	80	8	2.00	0.0416	4.106
54.0	150	8	2.50	0.0514	5.263
81.0	225	8	3.00	0.0391	5.242
144.0	400	8	4.00	0.0291	5.411

Kw@ 6kW/m/m	Flowrate (LPS)	Pressure (Bar-g)	Pipe size (inch)	DP (bar/100m)	Velocity (m/s)
1.8	5	7	0.5	0.1122	3.188
3.6	10	7	0.75	0.0992	3.633
5.4	15	7	1	0.0628	3.363
9.0	25	7	1.25	0.0441	3.334
14.4	40	7	1.50	0.0453	3.807
28.8	80	7	2.00	0.0468	4.619
54.0	150	7	2.50	0.0578	5.921
81.0	225	7	3.00	0.0440	5.897
144.0	400	7	4.00	0.0328	6.088

PRESSURE DROP IN FITTINGS

Equivalent length in metres											
Component	Inner pipe diameter in mm (d)										
	25	40	50	80	100	125	200	250	250	300	400
Ball valve (full flow) 	0.3 5	0.5 8	0.6 10	1.0 16	1.3 20	1.6 25	1.9 30	2.6 40	3.2 50	3.9 60	5.2 80
Diaphragm valve fully open 	1.5	2.5	3.0	4.5	6	8	10	-	-	-	-
Angle valve fully open 	4	6	7	12	15	18	22	30	36	-	-
Poppet valve 	7.5	12	15	24	30	38	45	60	-	-	-
Flap check valve 	2.0	3.2	4.0	6.4	8.0	10	12	16	20	24	32
Elbow R = 2d 	0.3	0.5	0.6	1.0	1.2	1.5	1.8	2.4	3.0	3.6	4.8

PRESSURE DROP IN FITTINGS

Equivalent length in metres												
Component		Inner pipe diameter in mm (d)										
		25	40	50	80	100	125	200	250	250	300	400
Elbow R = d		0.4	0.6	0.8	1.3	1.6	2.0	2.4	3.2	4.0	4.8	6.4
90° angle		1.5	2.4	3.0	4.5	6.0	7.5	9	12	15	18	24
Tee through-flow		0.3	0.4	1.0	1.6	2.0	2.5	3	4	5	6	8
Tee side-flow		1.5	2.4	3.0	4.8	6.0	7.5	9	12	15	18	24
Reducing nipple		0.5	0.7	1.0	2.0	2.5	3.1	3.6	4.8	6.0	7.2	9.6

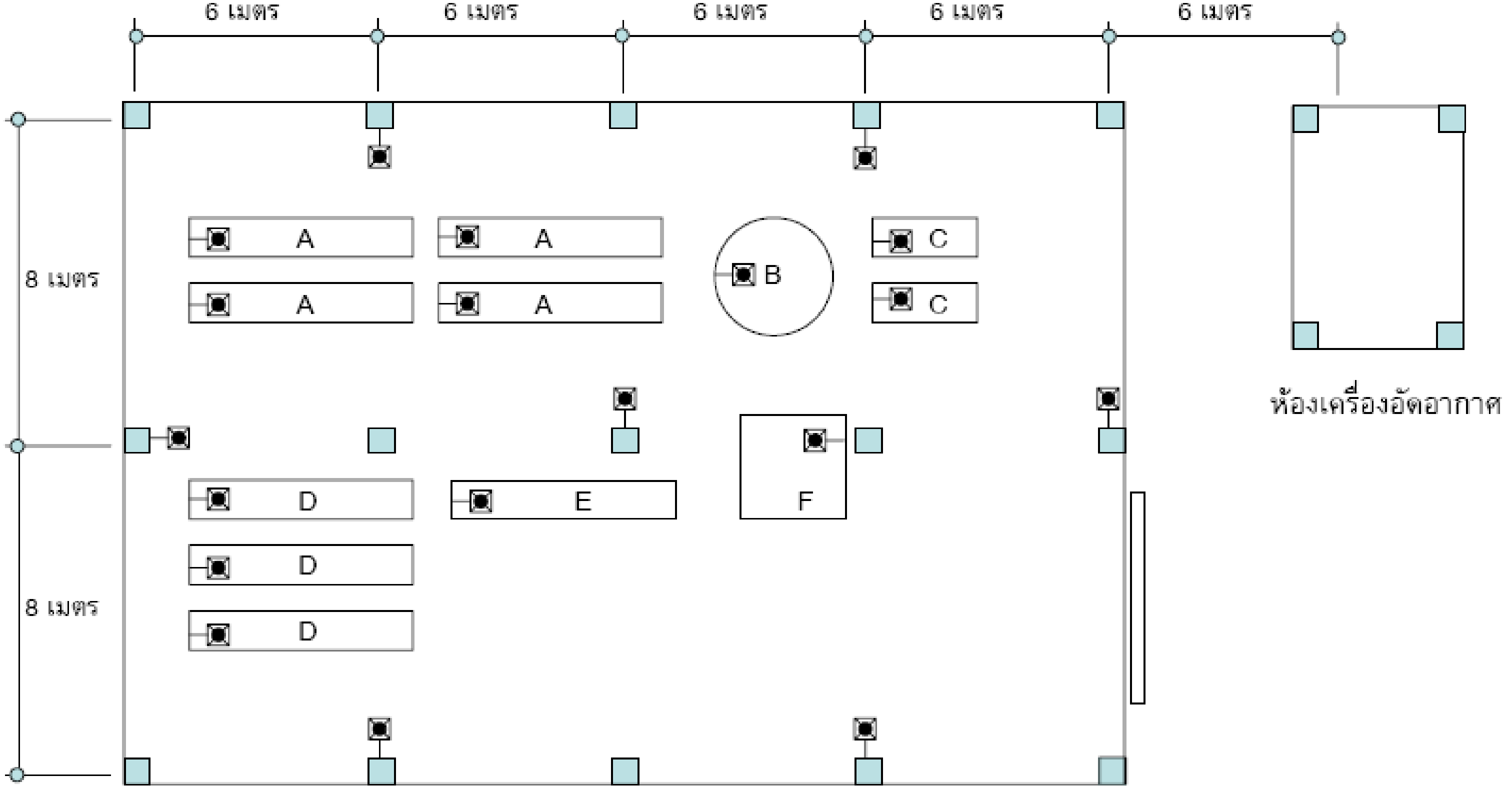
INLET PIPE SIZE

Maximum cfm free-air capacity l/s		Minimum size	
		NPS	DN
50	25	2½	65
110	55	3	80
210	105	4	100
400	200	5	125
800	400	6	150

SIZING THE RECEIVER

- 20 l/kW
- 10S of compressor capacity for constant load
- 20S of compressor capacity for fluctuated load

EXAMPLE


6 เมตร
6 เมตร
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D
D
D
E
F
ห้องเครื่องอัดอากาศ

FINAL NOTES

1. DESIGN PROCESS START FROM THE END USER
   - END USER REQUIREMENT
   - SOURCE
   - PIPING SYSTEM

2. SOME SYSTEM ARE NOT INCLUDED SUCH AS
   - FIRE FIGHTING SYSTEM (SEE EIT STANDARD)
   - HIGH PRESSURE STEAM
   - OIL PIPELINE
   - MUNICIPALITY WATER DISTRIBUTION NETWORK

3. PIPING SYSTEM COST 7-8% OF A CONSTRUCTION PROJECT
   - OPERATING COST IS MUCH MORE
   - DO NOT UNDERSIZE THE PIPE

RECOMMENDED COURSE