

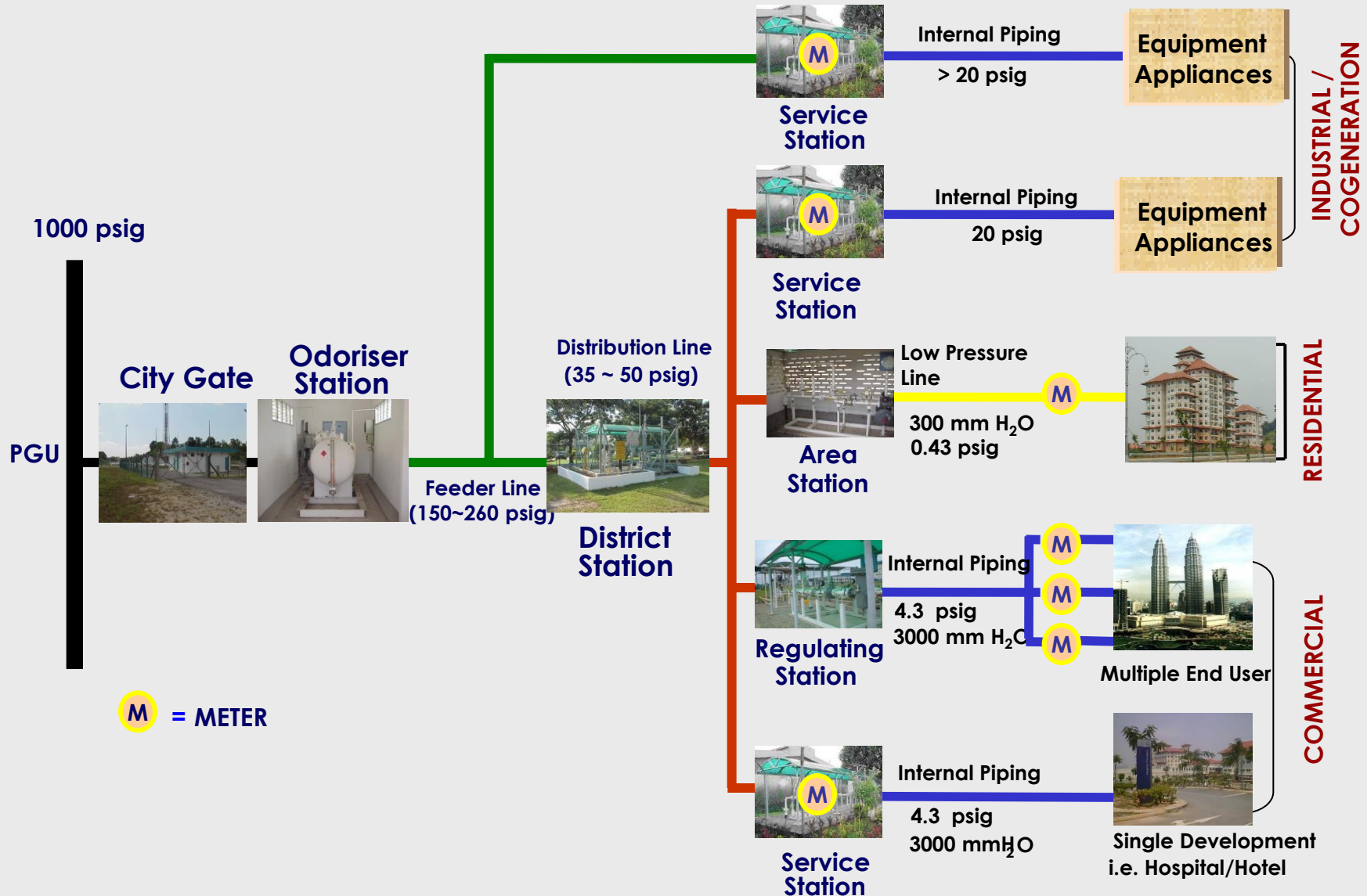


CHAPTER 4

GAS BURNER

CONVERSION

NATURAL GAS SUPPLY CONCEPT

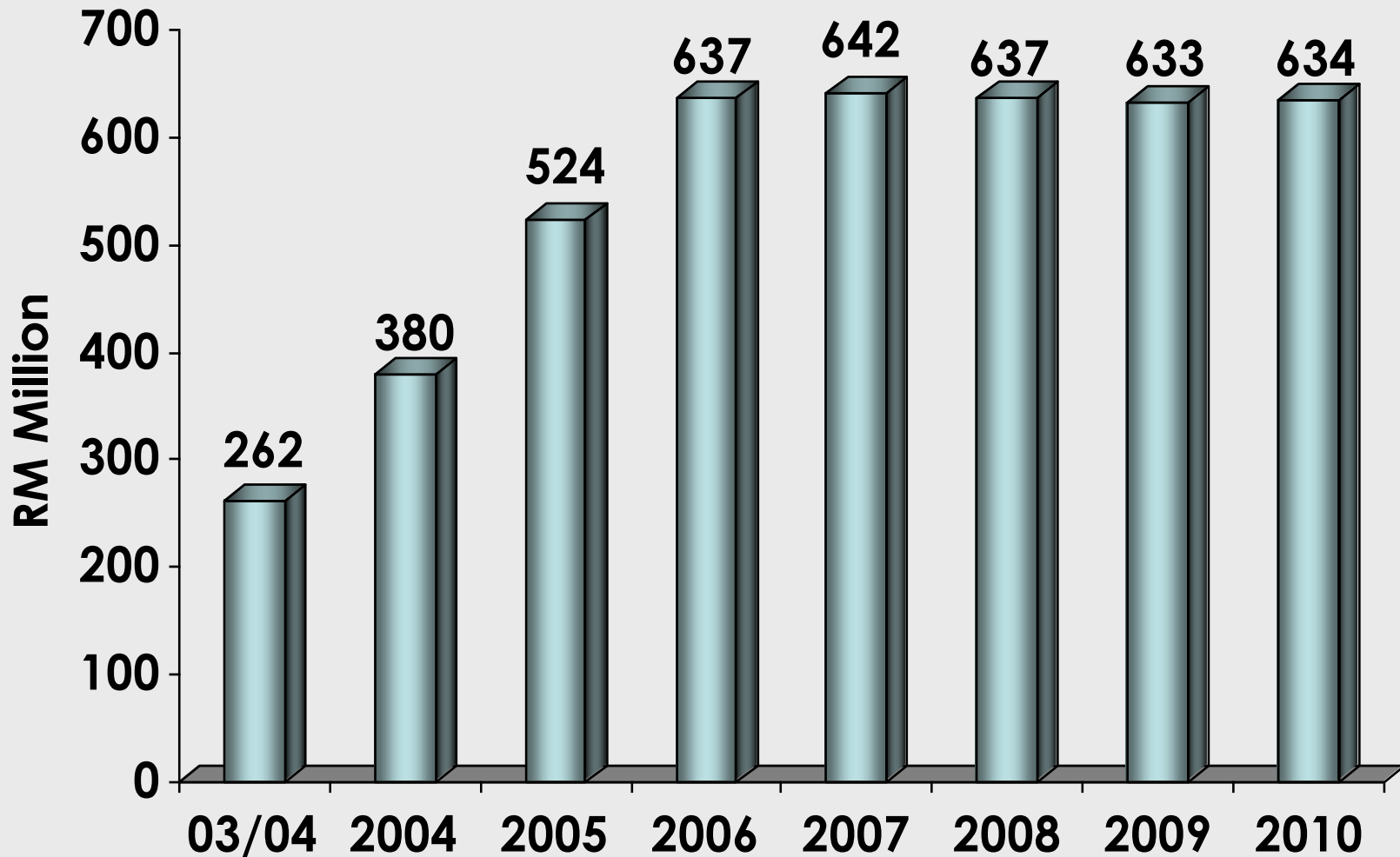


GAS MALAYSIA : NO OF CUSTOMERS

NO OF CUSTOMERS	NATURAL GAS	LPG	TOTAL
Industrial	636		636
Commercial	439	709	1,148
Residential	6,232	23,270	29,502
Total	7,307	23,979	31,286

As of July 2008

GAS MALAYSIA :- INDUSTRIAL CUSTOMER TREND



Introduction to Burner

Burners can be defined as a device used to produce heat or flame from the chemical reaction between the fuel (gas/liquid/solid hydrocarbon and non-hydrocarbon) with oxidizing agents (mainly oxygen in air) - known as combustion

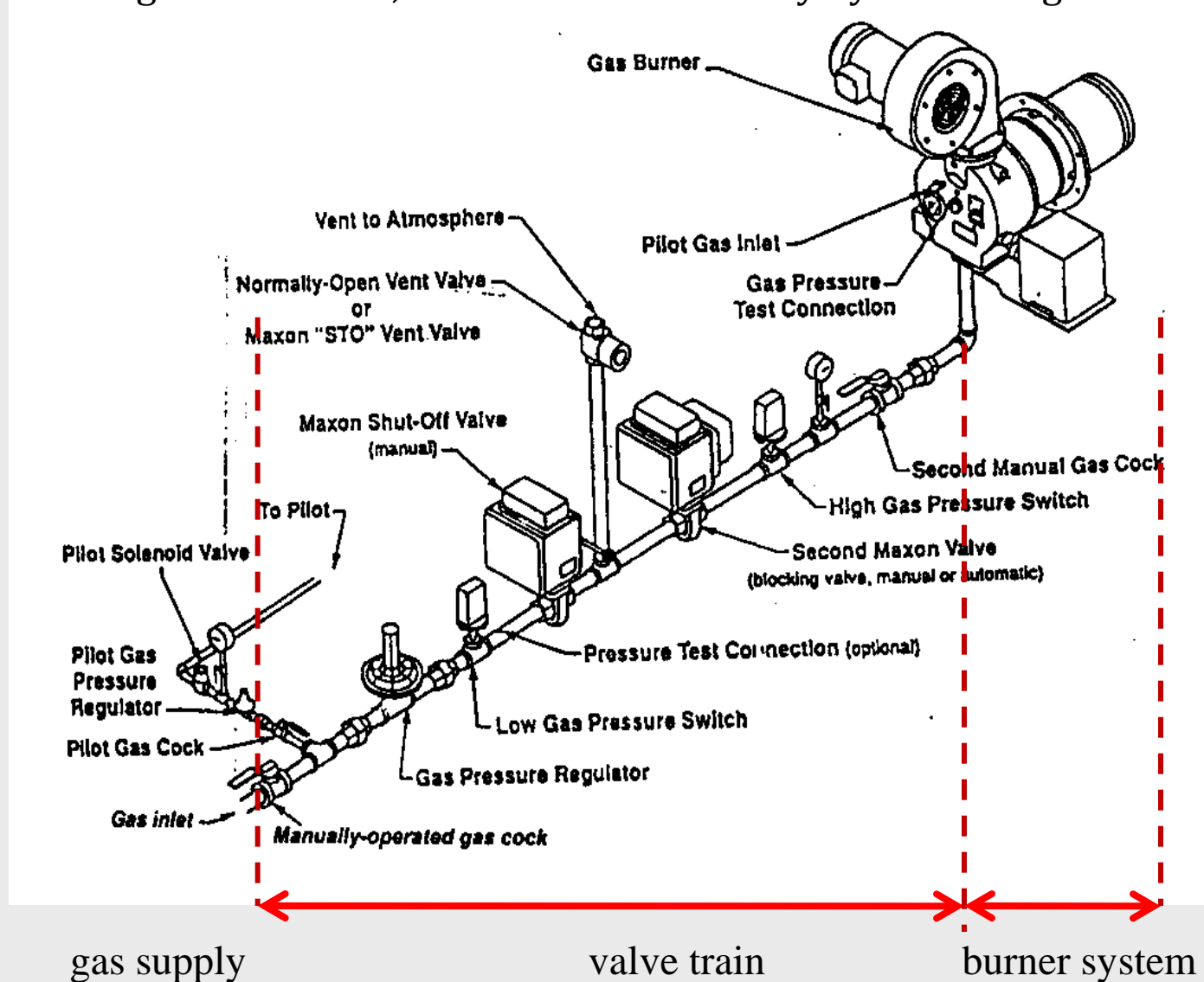
3 types of burner; gas fuel, liquid fuel and solid fuel burner

What is burner function?

- Send fuel and combustion air to combustion chamber
- Mixing fuel and air (fuel/air mixing)
- Provide ignition of the fuel and air mixture and ensure continuous and stable combustion

Burner System

The main components of the combustion system that is responsible for the heat required for usage in domestic, residential and industry by action of gas fuel with air



Why Gas Burner Conversion

- The needs for interchangeability of fuel
 - Fuel supply shortage (continuous vs. batch supply)
 - Fuel price fluctuations
 - Environmental concerns
- Main factors influencing decision
 - Infrastructure (pipeline location)
 - Energy consumption (intensive vs non-intensive)

PGU 2



Interchangeability of fuel

Consideration include:-

Equal heat input

Heat input of natural gas = heat input of fuel being replaced

Combustion or flame stability

Flame speed & flammability limit

Combustion air requirement

Air supply devices such as blower, fan, compressor etc.

Interchangeability of fuel

Heat release pattern

- a) Temperature distribution
- b) Flame shape / luminosity / radiation intensity

Handling capability

- Flue gas venting
- Burner types
- Piping, valves & controls (size and operating range)

Conversion of other fuel to Natural Gas

Conversion from other **gaseous** fuels

- Simple, depending on the type of burner and the characteristics of other fuel
- Two gases have the same Wobbe index, then they can be interchange with no significant physical changes to burner
- Problems such as air requirements, combustion stability often encountered

Conversion from other **liquid** fuels

- In most cases require a completely new burner
- With dual fuel (oil/gas) burner, conversion of existing gas firing system is possible

Conversion from other **solid** fuels

- Require a completely new burner, piping and control system

Important fuel properties

1. Components of gaseous fuel

Item		Natural Gas Before '95	Natural Gas After '95'	LPG
Gas components				
Methane	CH ₄ (vol. %)	84.75	92.74	
Ethane	C ₂ H ₆ (vol. %)	10.41	4.07	
Propane	C ₃ H ₈ (vol. %)	0.98	0.77	30
Butane	C ₄ H ₁₀ (vol. %)	0.11	0.14	70
Nitrogen	N ₂ (vol. %)	0.39	0.45	
Carbon dioxide	CO ₂ (vol. %)	3.36	1.83	

2. Relative Density (Specific gravity)

$$SG = \frac{\rho_{fuel}}{\rho_{air}}$$

- SG has two practical importance
 - Effect on the flow of gases through orifices or pipe
 - Rating of burners – burner conversion
- SG depends very much on its gas mixture composition

- $SG = \sum_{i=1}^{i=n} y_i SG_i$
- where y_i = mole fraction (vol. %) of fuel component i
 SG_i = specific gravity of fuel component i

Fuel	Relative (mol) weight	Specific weight at 0°C & atm. (kg/m ³)	Specific gravity (air=1)
Hydrogen (H ₂)	2.020	0.0898	0.0695
Methane (CH ₄)	16.04	0.7167	0.5540
Ethane (C ₂ H ₆)	30.07	1.3567	1.0494
Propane (C ₃ H ₈)	44.10	2.0200	1.5625
Butane (C ₄ H ₁₀)	58.12	2.5985	2.085
Carbon monoxide (CO)	28.01	1.2501	0.9670
Carbon dioxide (CO ₂)	44.01	1.9768	1.5291
Oxygen (O ₂)	32.00	1.4289	1.1053
Nitrogen (N ₂)	28.02	1.2507	0.9674
Water vapour (H ₂ O)	18.02	0.8040	0.6219
Air	28.97	1.2928	1.000

3. Calorific or heating value

- Quantity of heat release from combustion of unit weight or volume of fuel (MJ/kg or Kcal/kg or Kcal/ m³ or MJ/m³)
- The more carbon and hydrogen atoms in each molecule of a fuel the higher will be its CV or heating value.
- The larger the amount of inert matters, such as nitrogen and carbon dioxide, or water content, present in a fuel the lower the CV will be.

Calorific value of multicomponent fuel can be calculated as follows ;

$$CV = \sum_{i=1}^{i=n} y_i CV_i$$

where y_i = mole fraction (vol. %) of fuel component i
 CV_i = calorific value of fuel component i per unit volume

and CV per unit weight = CV per unit volume/specific weight

Calorific value	Per unit volume		Per unit per weight	
	Gross	Net	Gross	Net
Fuel	Kcal/Sm ³ Btu/Sm ³	Kcal/Sm ³ Btu/Sm ³	Kcal/kg Btu/kg	Kcal/kg Btu/kg
Hydrogen (H ₂)	2893 11480	2439 9679	33998 134913	28653 113702
Methane (CH ₄)	9041 35877	8128 32254	13307 52806	11936 47472
Ethane (C ₂ H ₆)	15958 63352	14578 57849	12408 49238	11336 44984
Propane (C ₃ H ₈)	22968 91143	21108 83762	11995 47599	11023 43742
n-Butane (n-C ₄ H ₁₀)	30355 120456	27983 111104	12323 48901	11360 45079
i-Butane (i-C ₄ H ₁₀)	30127 119552	27764 110175	12231 48586	11272 44730

Calorific value	unit	Natural Gas	Natural Gas	LPG
		Before '95	After '95	Commercial
Gross	(Kcal/m ³) (Btu/m ³) (Kcal/kg)	9582 38024 11992	9253 36718 12487	28059 111345 11889
Net	(Kcal/m ³) (Btu/m ³) (Kcal/kg)	8644 34302 10816	8333 33067 11246	25844 102556 10951

4. Wobbe Index

- For a given pressure of fuel gas at the burner, the flow rate is proportional to the calorific value and inversely proportional to the square root of the density of the gas,

$$Q \propto \frac{CV}{\sqrt{SG}}$$

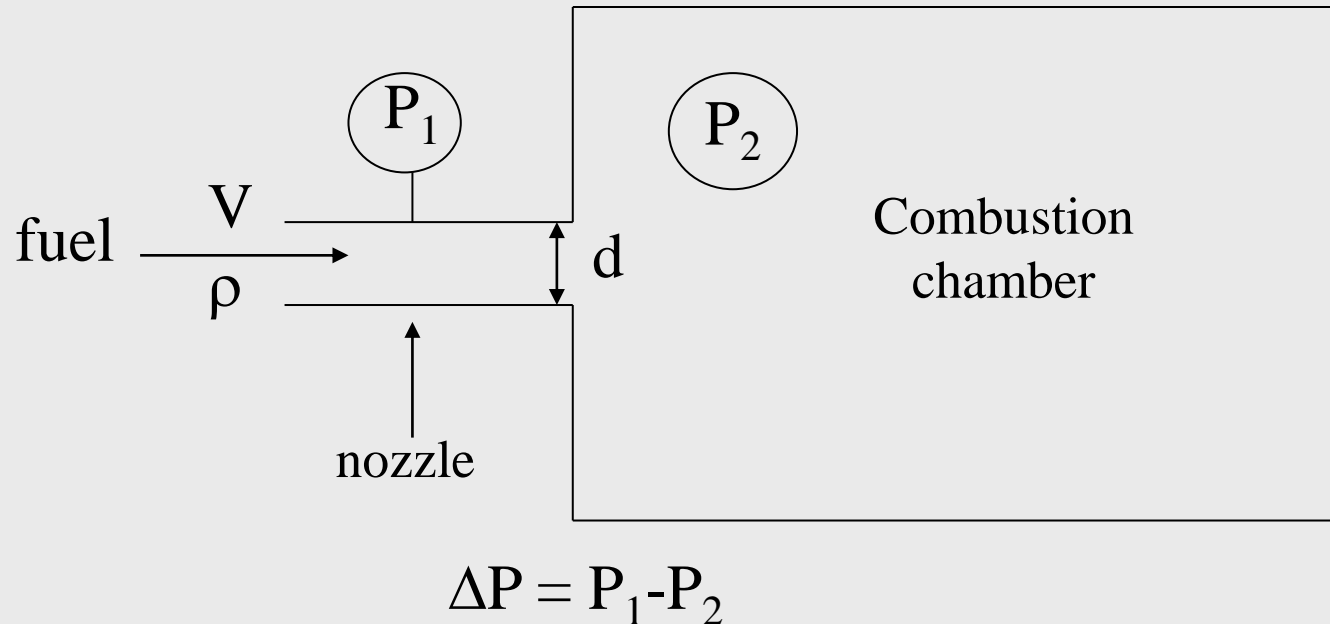
$\frac{CV}{\sqrt{SG}}$ is known as Wobbe number or index

Calorific value	unit	Natural Gas	Natural Gas	LPG
		Before '95	After 95'	Commercial
Gross	(Kcal/m ³)	9582	9253	28059
	(Btu/m ³)	38024	36718	111345
	(Kcal/kg)	11992	12487	11889
Net	(Kcal/m ³)	8644	8333	25844
	(Btu/m ³)	34302	33067	102556
	(Kcal/kg)	10816	11246	10951

COMPARISON OF THE PROPERTIES OF TYPICAL GASES

Property	Units	NG	Commercial Propane	Butane/Air Mixtures
CV	MJ/m ³	39.3	97.3	23.75
SG	air=1	0.58	1.5	1.19
Wobbe #	MJ/m ³	51.64	79.4	21.79
Air Required	Vol air/Vol gas	9.75	23.8	4.89
Flammability Limits	% gas in air	5 to 15	2 to 10	1.6 to 7.75
Flame Speed	m/s	0.36	0.46	0.38
Ignition T	°C	704	530	500

NG Burner Conversion (e.g. LPG to NG)



- **Conversion requirements**
 - Same energy input
 - Same or acceptable air/fuel ratio
 - Same or better productivity or production quality

Flow Equations

$$V = kd^2 \left(\frac{P_1 - P_2}{SG} \right)^{0.5} = kd^2 \left(\frac{\Delta P}{SG} \right)^{0.5} \dots\dots(1)$$

where

V = volumetric as flow rate

d = nozzle diameter

P = gas pressure

SG = Specific gravity

k = constant

ΔP = pressure drop across the nozzle

Energy Equation

$$Q = V \times CV_{\text{fuel}} \dots\dots\dots(2)$$

where

Q = heat input

CV_{fuel} = gas calorific or heating value

Requirement 1 : same energy input, i.e. $Q_{\text{NG}} = Q_{\text{LPG}}$

$$Q_{\text{NG}} = Q_{\text{LPG}} \dots\dots\dots(3)$$

$$V_{\text{NG}} CV_{\text{NG}} = V_{\text{LPG}} CV_{\text{LPG}} \dots\dots\dots(4)$$

$$kd_{\text{NG}}^2 \left(\frac{\Delta P}{SG_{\text{NG}}} \right)^{0.5} CV_{\text{NG}} = kd_{\text{LPG}}^2 \left(\frac{\Delta P}{SG_{\text{LPG}}} \right)^{0.5} CV_{\text{LPG}} \dots(5)$$

....rearranging equation (5)

$$kd_{NG}^2 \Delta P^{0.5} \left(\frac{CV_{NG}}{\sqrt{SG_{NG}}} \right) = kd_{LPG}^2 \Delta P^{0.5} \left(\frac{CV_{LPG}}{\sqrt{SG_{LPG}}} \right) \dots\dots\dots(6)$$

$$kd_{NG}^2 \Delta P^{0.5} WI_{NG} = kd_{LPG}^2 \Delta P^{0.5} WI_{LPG} \dots\dots\dots(7)$$

$$WI = \frac{CV}{\sqrt{SG}} \dots\dots\dots(8)$$

- **WI** is Wobbe number or Wobbe Index, an indication of interchangeability of fuel gas.
- Gaseous fuel having the same WI can be interchanged with no significant physical changes to the burner

..... Interchangeability correlation

$$kd_{NG}^2 \Delta P_{NG}^{0.5} WI_{NG} = kd_{LPG}^2 \Delta P_{LPG}^{0.5} WI_{LPG} \dots\dots\dots(7)$$

equation (7) shows that if the WI of the substitutes gas (i.e. NG) is different from that of the replaced gas (i.e. LPG), it can be successfully interchanged by two ways

- nozzle replacement or modification
- gas pressure adjustment

$$kd_{NG}^2 \Delta P_{NG}^{0.5} WI_{NG} = kd_{LPG}^2 \Delta P_{LPG}^{0.5} WI_{LPG} \dots\dots\dots(7)$$

Method 1 : Nozzle replacement or modification

- Keeping the pressure drop term constant and rearranging equation (7)

$$\left(\frac{d_{NG}}{d_{LPG}} \right) = \left(\frac{WI_{LPG}}{WI_{NG}} \right)^{0.5} \dots\dots\dots(9)$$

Method 2 : Gas pressure adjustment

- Keeping the nozzle or orifice diameter term constant and rearranging equation (7)

$$\left(\frac{\Delta P_{NG}}{\Delta P_{LPG}} \right) = \left(\frac{WI_{LPG}}{WI_{NG}} \right)^2 \dots\dots\dots(10)$$

Requirement 2 : same air-fuel ratio

- After the energy input adjustment is successfully achieved, the combustion air should be adjusted to get a proper air-fuel ratio, and hence temperature profile
- This can be calculated from the energy based theoretical air (TA) requirement, defined as a ratio of combustion air supplied (Sm³) to heat generated (kcal, kW, BTU etc.)

$$TA_{NG} = \frac{CV_{NG}}{V_{air,NG}}$$

$$TA_{LPG} = \frac{CV_{LPG}}{V_{air,LPG}}$$

TA_{NG}	1.05 Sm³/Mcal
TA_{LPG}	1.03 Sm³/Mcal

- Important consideration points of NG conversion (from LPG) for the same performance (i.e. Heat Input)
 - NG flow rate is higher than LPG due to its lower calorific value.
 - NG pressure is higher than LPG if the pressure adjustment method is to be used.
 - NG will have higher pressure drop in the gas supply system.
 - NG firing requires higher combustion air

- **Final confirmation methods**

After natural gas conversion, same performance and productivity are required hence confirmation methods should be considered

- Flow rate of natural gas should be corrected based on the following equation

V_i = Flow rate of gas as recorded by a rotameter

V_a = Actual flow rate of gas

T = absolute temperature

P = absolute pressure

SG = Specific gravity of gas

c = design base of meter

a = actual gas conditions

Gas metering !!!

$$V_a = V_c \left[\frac{T_a}{T_c} \right] \left[\sqrt{\frac{SG_c P_a}{SG_a P_c}} \right]$$

- **Flue gas analysis**

- Oxygen or CO measurement is recommended to check whether proper air/gas ratio and firing is obtained
- This is also for safety and furnace/boiler efficiency analysis

- **Pressure measurements**

- Pressure, both air and gas, should be measured at suitable points to check the firing condition and also their maintenance

- **Heating up period**

- If the energy input and air/gas ratio are the same as for LPG firing, the same heating up period should be obtained
- This is very important for small appliances which have no gas meter

- **Product confirmation**

- Check for product defect, rate and efficiency – higher productivity and efficiency and lower production defects are desired.

- **Important considerations of capacity of equipment used in burner conversion**

Natural gas firing requires higher gas flow rate and the capacity of the maximum flow rate or pressure limitation should be considered for the following equipment

Equipment	Checking points
Gas burner	Orifice size, operating pressure
Gas meter	Flow rate capacity, pressure limitation
Regulator	Flow rate capacity, pressure range & limitation
Shut-off valve	Pressure drop & limitation
Pressure gauge	Pressure range
Pressure switch	Pressure drop & limitation

Comparison of LPG and NG

Item		Natural Gas	Natural Gas	LPG
		Before '95	After '95	
Gas components				
Methane	CH ₄ (vol. %)	84.75	92.74	
Ethane	C ₂ H ₆ (vol. %)	10.41	4.07	
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Nitrogen	N ₂ (vol. %)	0.39	0.45	
Carbon dioxide	CO ₂ (vol. %)	3.36	1.83	
Specific gravity	(air = 1)	0.652	0.605	1.926
Specific weight	(kg/Sm ³)	0.799	0.741	2.36
Theoretical oxygen	(m ³ /m ³)	2.115	2.045	6.050
Theoretical air	(m ³ /m ³)	10.07	9.738	28.82
	(Sm ³ /Mcal)	1.05	1.05	1.03
Calorific value				
Gross	(Kcal/m ³)	9582	9253	28059
	(Btu/m ³)	38024	36718	111345
	(Kcal/kg)	11992	12487	11889
Net	(Kcal/m ³)	8644	8333	25844
	(Btu/m ³)	34302	33067	102556
		10816	11246	10951
Combustion products	(stoichiometric)			
CO ₂	(m ³ /m ³)	1.12	1.06	3.7
	(vol. %)	10.1	9.8	11.9
H ₂ O (vapour)	(m ³ /m ³)	2.05	2.01	4.70
	(vol. %)	18.4	18.7	15.1
N ₂	(m ³ /m ³)	7.96	7.7	22.76
	(vol. %)	71.5	71.5	73.0
Net Wobbe index		10705	10713	18604

Example 1

Item		Natural Gas	Natural Gas	LPG
		Before '95	After '95'	
Gas components				
Methane	CH ₄ (vol. %)	84.75	92.74	
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a) Compare the conversion requirements of LPG firing appliance to natural gas (after '95) with fuel composition as shown above and deduce conclusions with respect to

- Gas volume
- Gas supply pressure
- Nozzle or orifice diameter

Example 1

b) Also perform necessary calculations to show that the most important consideration factor of burner conversion requirement cannot be met if natural gas is directly fired into a LPG gas appliance without undergoing burner modification or adjustment

Group work

Please do Example 1

Compare the conversion requirements of LPG firing appliance to natural gas with composition before 1995.

Question?



THE END

Thank You for the Attention
