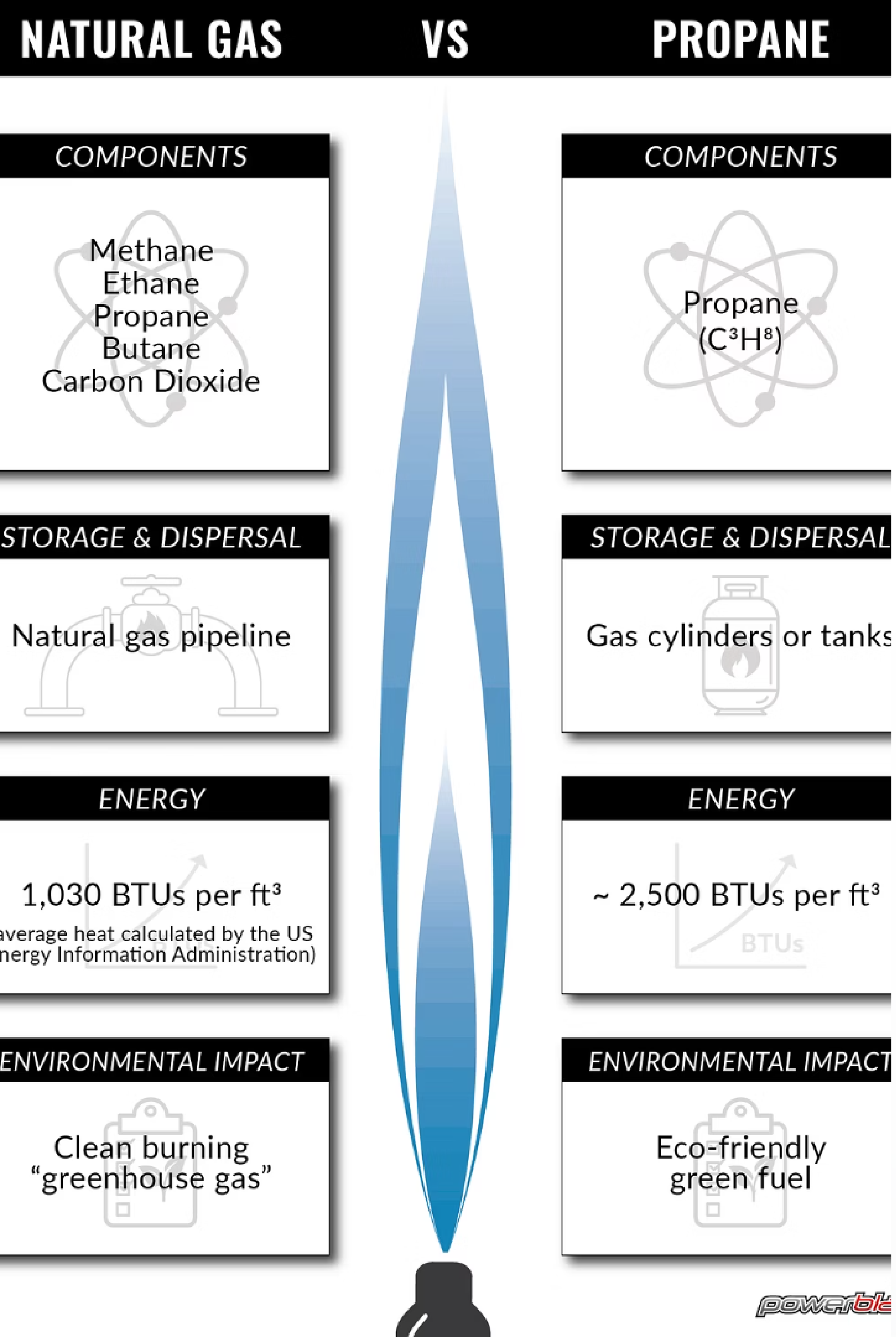


CSA Unit 3 - Properties and Safe Handling of Fuel Gases Chapter 1

A gas technician/fitter must know the physical properties and combustive elements of the most common fuel gases. If their physical properties are understood, the technician/fitter can troubleshoot and adjust equipment appropriately.

MK Created
by Mike Kapin

Course Objectives

Describe Common Fuel Gases

Understand the composition and sources of natural gas and propane

Identify Properties and Characteristics

Learn the physical properties of natural gas and propane that affect their handling and use

Identify Combustion Data

Understand how fuel gases burn and the factors that affect combustion

Key Terminology

Boiling Point

Temperature at which the vapour pressure of the liquid equals the pressure surrounding the liquid and the liquid changes into a vapour

Boyle's Law

$p_1V_1 = p_2V_2$ Absolute pressure that a given mass of an ideal gas exerts is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system

British Thermal Units (Btu)

Amount of energy needed to cool or heat one pound of water by 1°F

More Key Terminology

Calorific Value

Energy released during combustion of a given volume of fuel

Dry Gas

Natural gas with all the heavier hydrocarbons removed

Natural Gas

Naturally occurring mixture of hydrogen (H) and carbon (C) and other gases. Usually represented by the chemical formula for methane (CH_4)

Additional Terminology

Kilopascal (kPa)	Unit of pressure measurement
Mega joules per cubic meter (MJ/m3)	Measurement for calorific value
Mercaptan	Odorant added to natural gas and propane for safety
Pounds per square inch gauge (psig)	Pressure measurement relative to atmospheric pressure
Specific gravity	Comparison between the weight of the volume of a vapour or liquid and the weight of an equal volume of air or water

Final Terminology

Upper Explosive Limit (UEL)

Highest concentration (percentage) of a gas or vapour in the air capable of producing a flash of fire in the presence of an ignition source

Vapour Pressure

Pressure that a vapour exerts in equilibrium with its solid or liquid phases

LP Gases

Hydrocarbons that have undergone refining, storage, and transport as a liquid under pressure (C3H8)

Formation of Natural Gas

Organic Matter Decay

When animal and vegetable matter decays in the absence of air, tiny organisms that function only in an oxygen-free environment form gases.

Methane Production

The most common gas formed is methane, which is the major ingredient in fuel gas. You can observe methane production at landfills, which isolates garbage and excludes air.

Fossil Fuel Creation

In swamps and tidal flats, you can see bubbles of methane gas rising through the mud. These are the beginnings of a millions-of-years-old process: the creation of fossil fuels, or petroleum gases.

Common Petroleum Gases

Natural Gas

Naturally occurring mixture of hydrogen and carbon gases

Propane

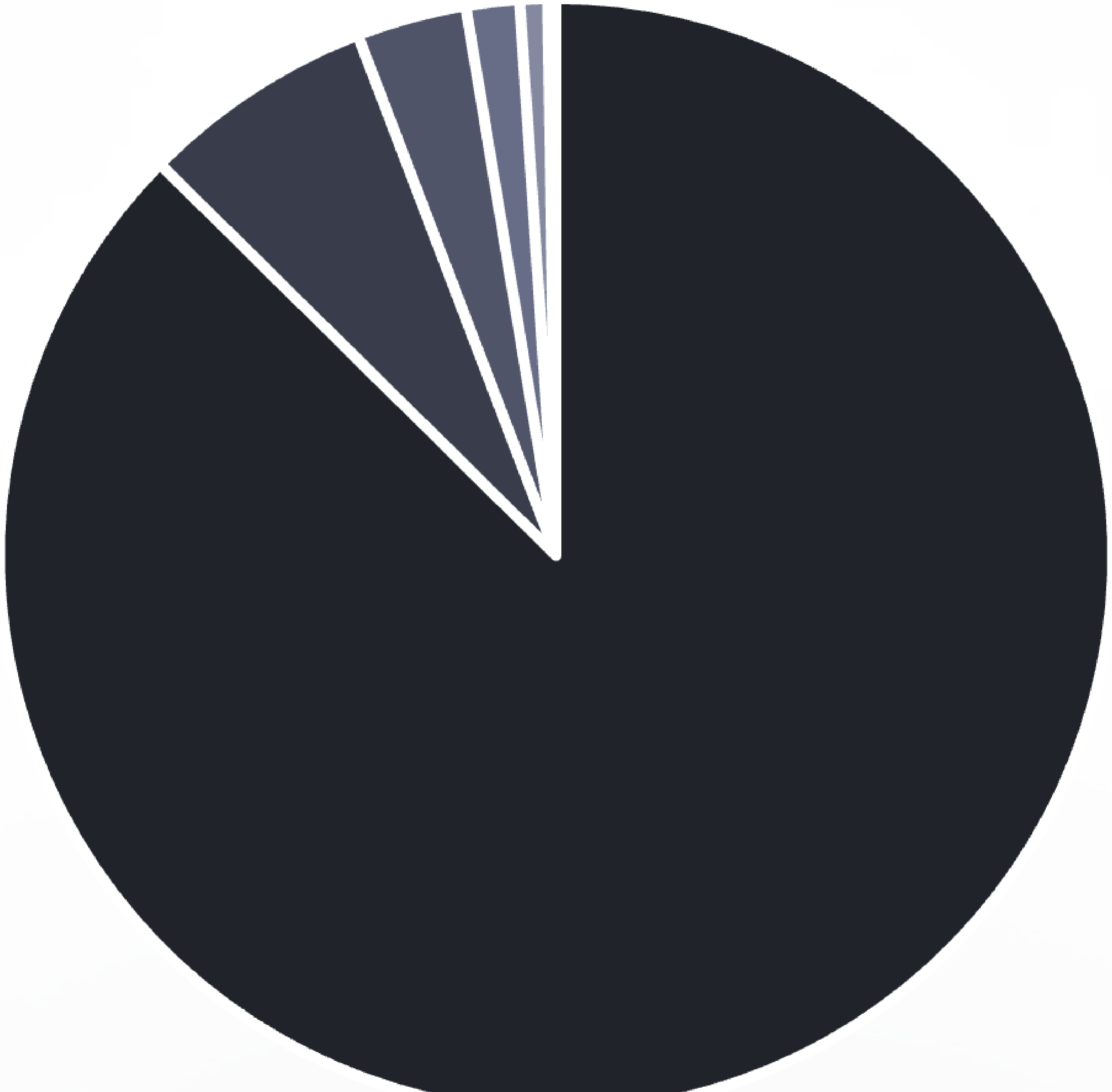
Processed derivative of natural gas

Butane

Processed derivative of natural gas

The petroleum gases that the gas industry most commonly use are natural gas and its two processed derivatives, propane and butane. In this course, you will deal with natural gas and propane. They come from a group of gases composed of hydrogen and carbon called hydrocarbons.

Natural Gas Composition



Methane: The Primary Component

Figure 1-1
The chemical structure of methane (CH_4)

Methane is also called "the gaseous phase of petroleum" because it is usually present wherever petroleum oil is in formation. It is the most stable of hydrocarbons, existing unchanged at temperatures of up to 1022°F (550°C).

Coal Seam Methane

Coal generates methane as it matures, and often, large quantities of natural gas can be found locked into coal seams.

Methane Structure

The chemical formula CH4 represents one carbon atom bonded to four hydrogen atoms in a tetrahedral structure.

Types of Natural Gas

Wet Gas

Wet gas is natural gas containing the heavier hydrocarbons: propane, butane, pentane, hexane, and heptanes. They are normally extracted immediately after the gas is brought to the surface. The gas industry uses the extracted propane and butane as liquefied petroleum gases (LP-gases).

Wet gas extracts are also valuable to the petrochemical industry.

Dry Gas

Dry gas is natural gas with all the heavier hydrocarbons removed. It is processed natural gas stored in underground storage tanks for use as a fuel gas.

More Types of Natural Gas

Sour Gas

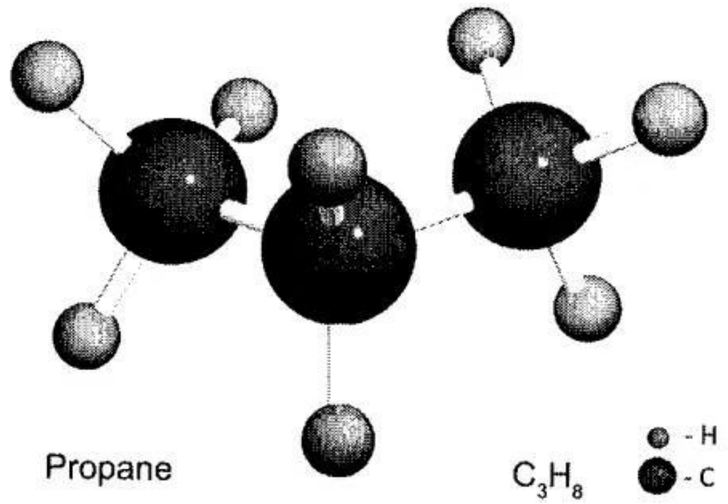
Sour gas contains a high percentage of hydrogen sulphide. It produces carbon black, a common ingredient used in rubber products.

Sweet Gas

Sweet gas is natural gas with little or no hydrogen sulphide content.

Propane

Figure 1-2
The chemical structure of propane (C_3H_8)



LP-gases (of which propane is the most common) are hydrocarbons extracted from both oil and natural gas that have undergone refinement, storage, and transportation as a liquid under pressure, followed by vapourization into a fuel gas when released for use in a gas burning appliance.

Chemical Structure

The chemical formula C_3H_8 represents propane, which consists of three carbon atoms bonded to eight hydrogen atoms.

Physical State

Under normal atmospheric temperature and pressure, propane is a gas. At cooler temperatures and at higher pressures, it easily changes into liquid form.

Composition of LP-Gas

Extraction

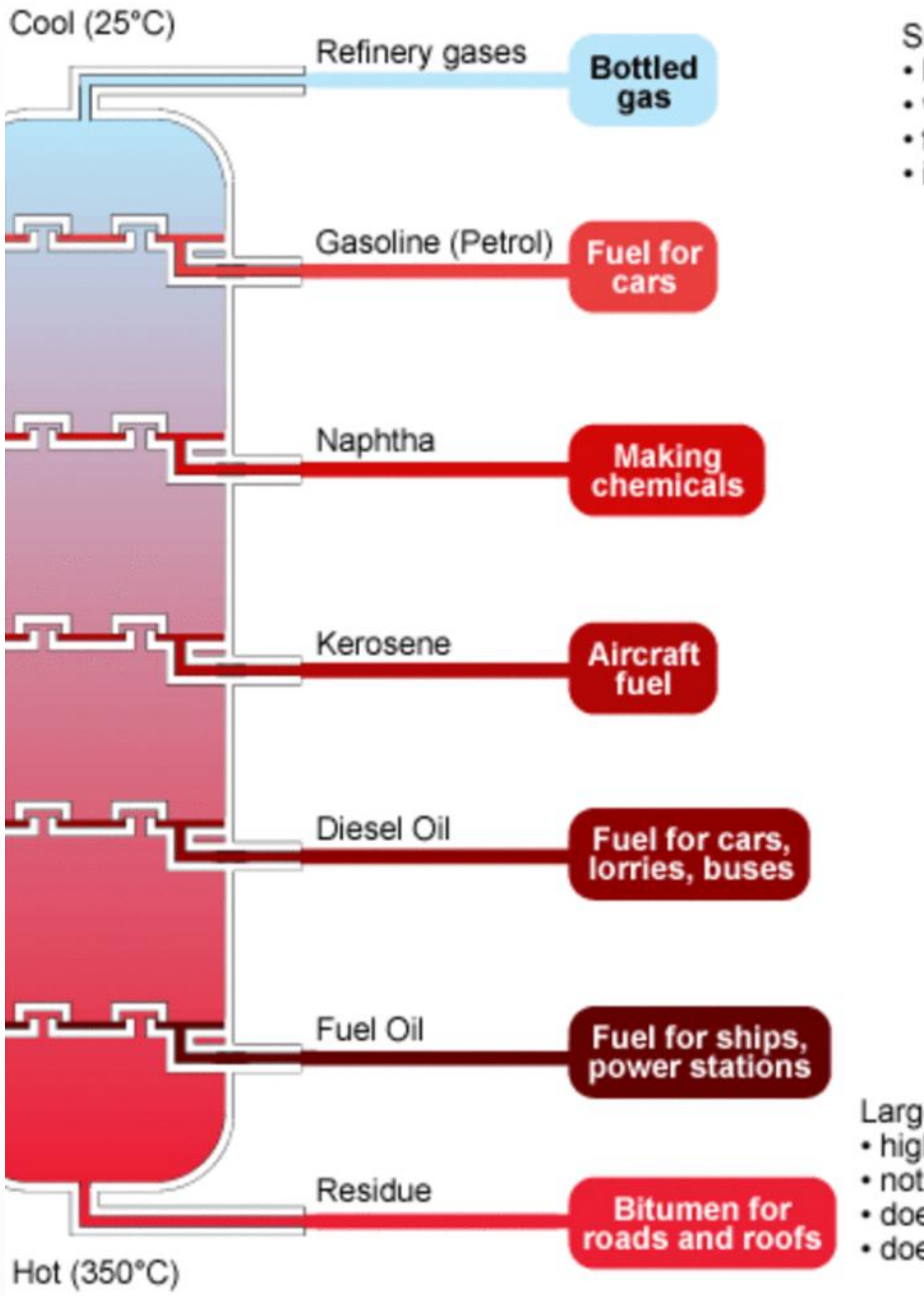
Both propane and butane are extracted from petroleum oil and natural gas.

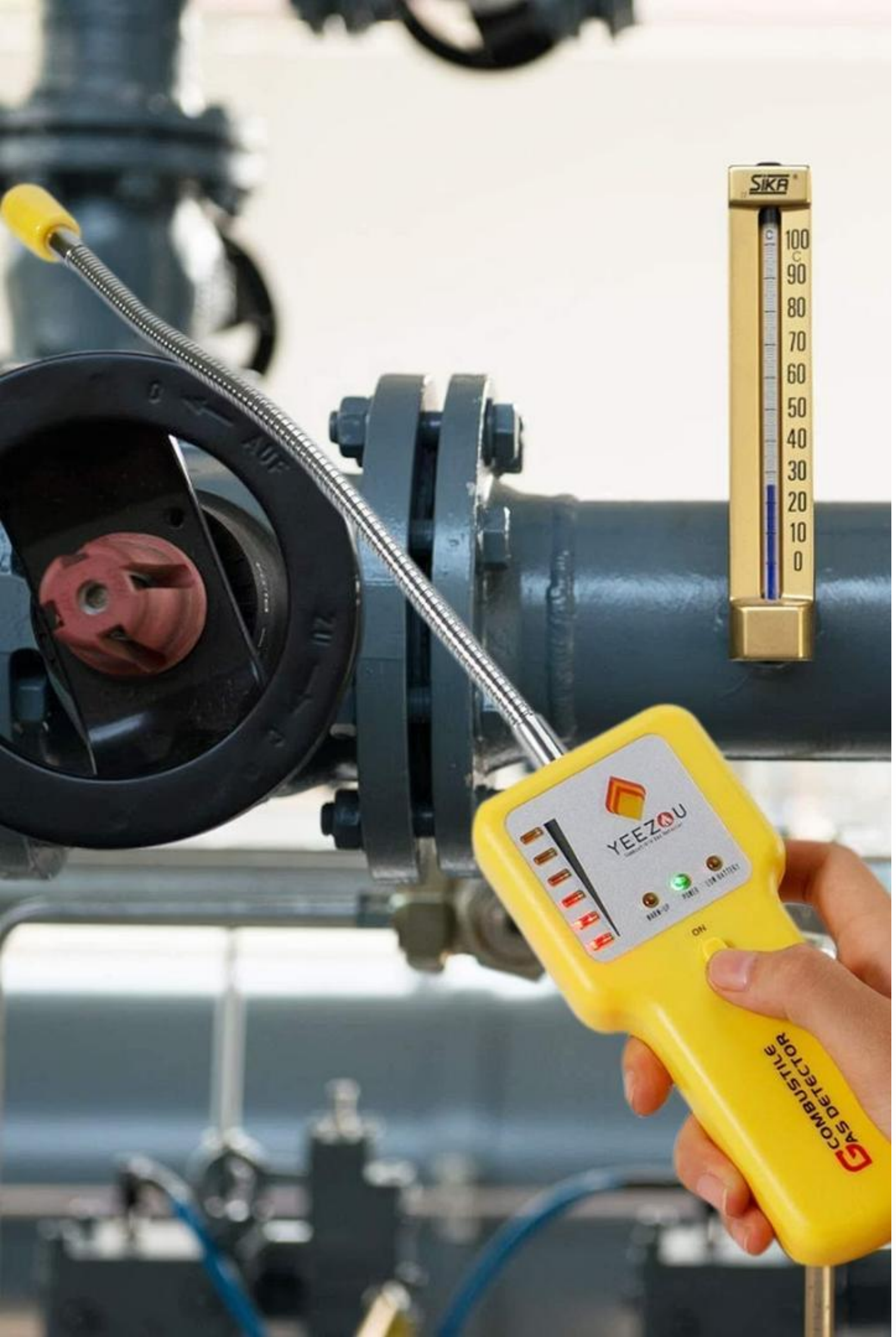
Separation

After their separation into a liquefied state from wet natural gas, fractionation (chemical separation) into their final processed forms occurs.

Final Processing

Processed propane is normally 100% pure. Butane, when processed, is 93% pure, with 7% propane added.





Common Properties of Fuel Gases

Invisible

Natural gas and propane cannot be seen with the naked eye

Odorless

In their natural state, these gases have no smell

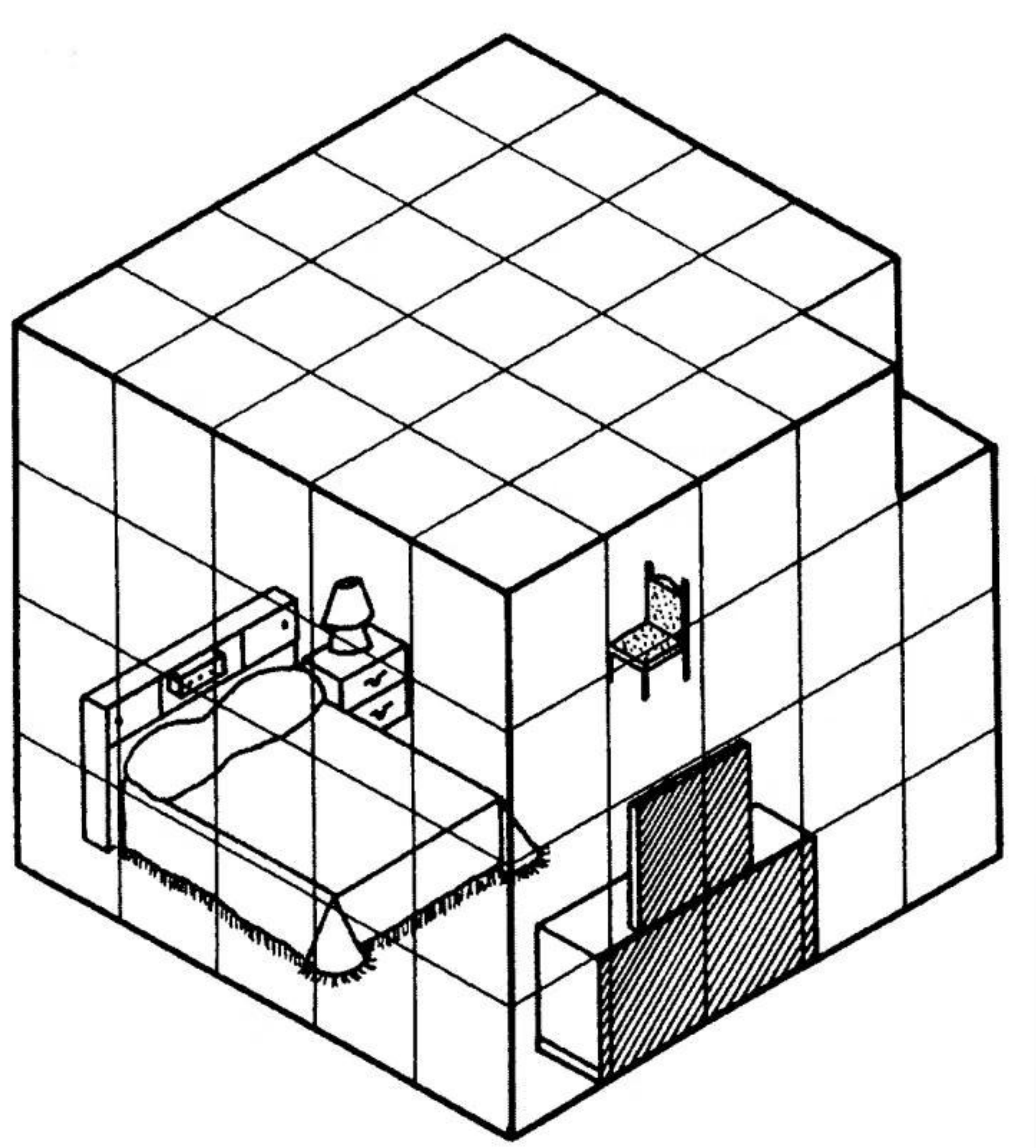
Tasteless

These gases have no taste that can be detected

Nontoxic

The gases themselves are not poisonous, though they can displace oxygen

Mercaptan: The Safety Odorant



Since your sense of smell cannot detect the gases, safety requires the addition of an odorant known as mercaptan to natural gas and propane. The chemical formula for ethyl

Purpose

Mercaptan alerts the user of a gas escape and the possible danger of explosion or fire.

Concentration

To detect a gas leak below its lower flammable limit, every one million cubic feet of gas should have approximately one pound of mercaptan.

Detection Standard

Odorization shall be readily detectable when fuel gas equals 1% of room volume.

Important Physical Properties

Specific Gravity

Comparison between the weight of a volume of gas and an equal volume of air

Expansion Factors

How gases expand when changing from liquid to gaseous state

Boiling Point

Temperature at which a liquid changes to a gas at atmospheric pressure

Temperature/Pressure

Relationship between temperature and pressure in gases

Calorific Value

Heat content or energy released during combustion

Specific Gravity

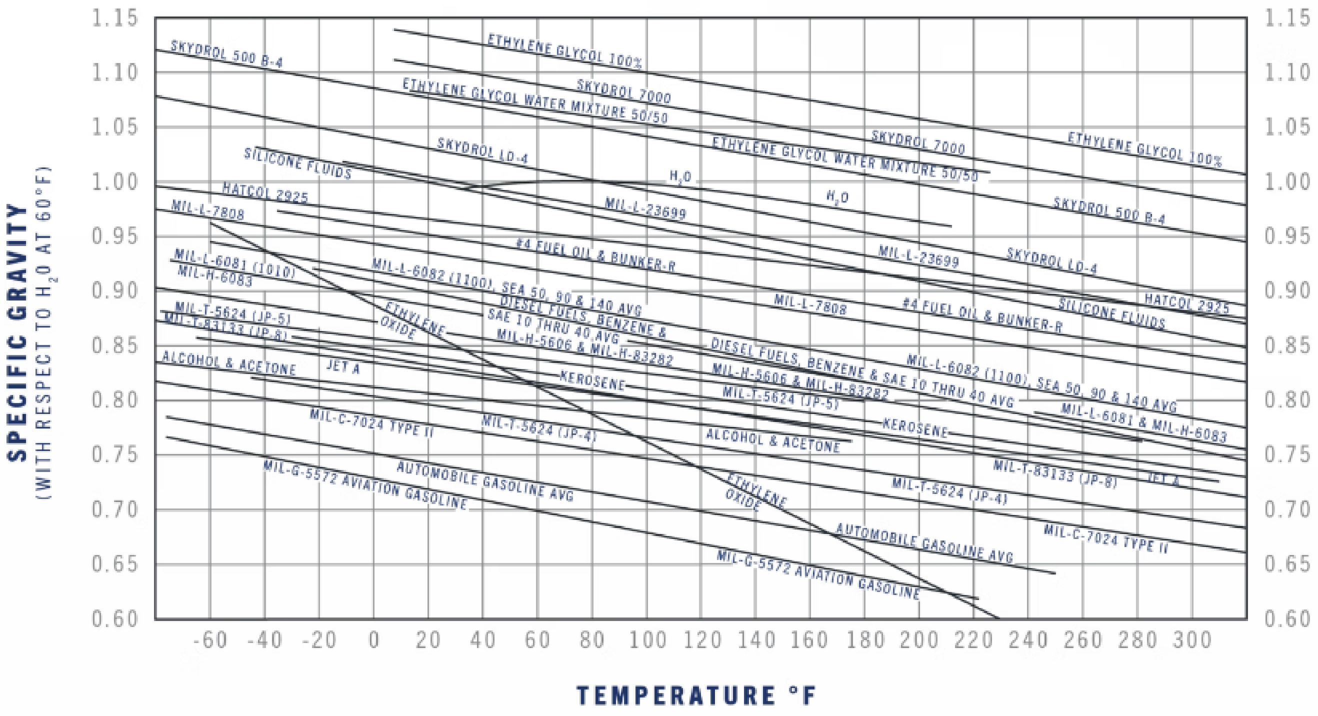
Definition

Specific gravity, or relative density, is the comparison between the weight of the volume of a vapour or liquid and the weight of an equal volume of air or water.

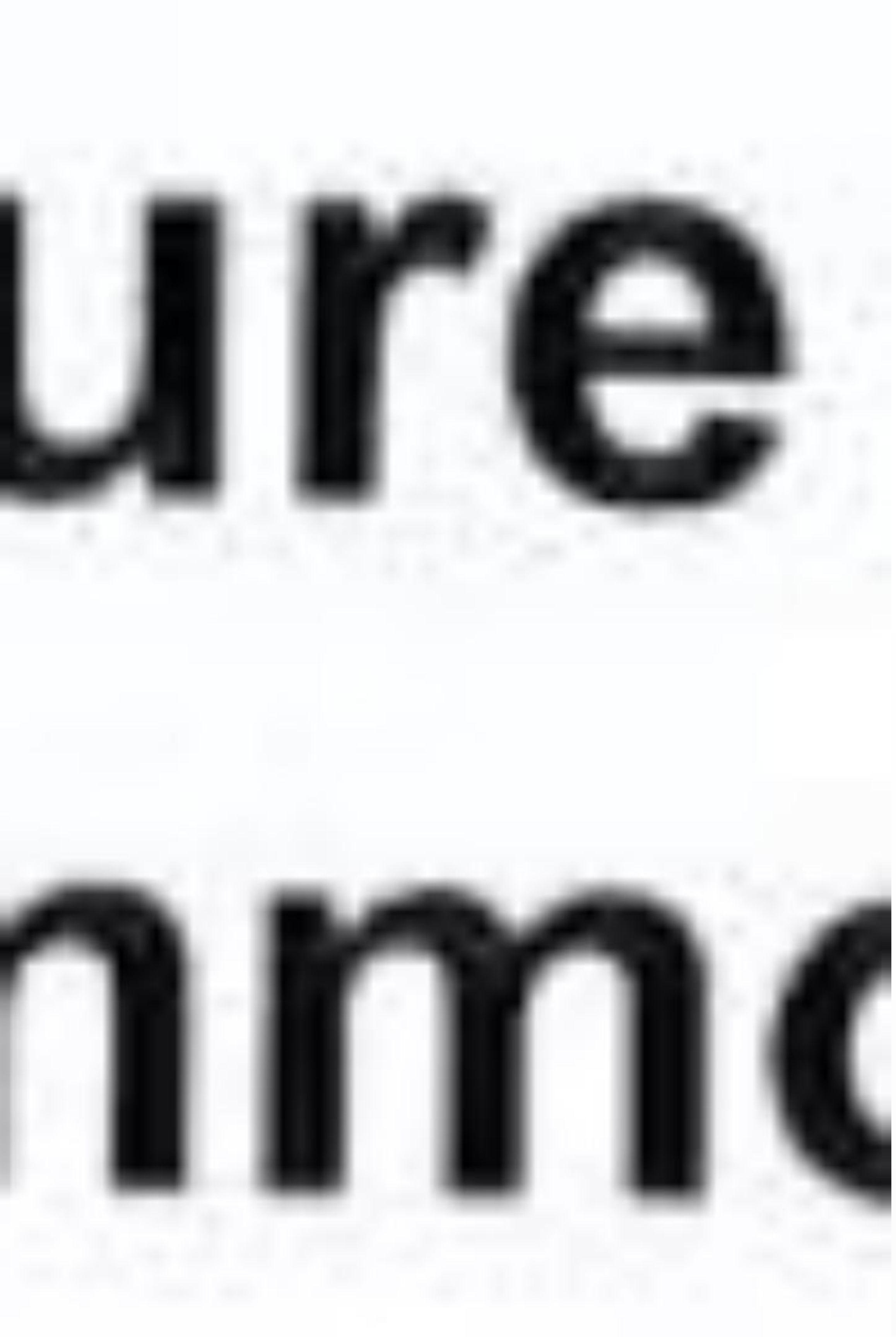
Importance

You must know the specific gravity of a gas when you are:

- Checking for gas leaks
- Calculating flows through gas piping systems
- Sizing orifices



When comparing the specific gravity of air and gas, ensure that both are at the same pressure and temperature.



Specific Gravity of Gases

0.55

Natural Gas

Lighter than air (air = 1.0)

1.0

Air

Reference standard

1.52

Propane

Heavier than air

1.95

Butane

Heaviest common fuel gas

With a specific gravity of 0.55, natural gas is lighter than air and will rise to the ceiling of a room. Both propane and butane are heavier than air, so if a leak develops in a gas line or appliance, LP-gas is likely to settle in low areas. This is an important consideration when trying to find the source of a leak or working where a leak has occurred.

Specific Gravity of LP-Gases as Liquids

Propane C_3H_8	0.509 or 0.51
Butane C_4H_{10}	0.58
[redacted]	1.0

Comparison to Water

The specific gravity of LP-gas is normally compared to water, which has a specific gravity of 1.0.

Practical Applications

Understanding liquid specific gravity can be useful in the following cases:

- During delivery of propane to a plant, the liquid specific gravity marked on a bill of lading helps you check the type and amount of LP-gas delivered.
- During filling, you may use the liquid specific gravity to determine the proper filling limit to prevent overfilling of the tank.

Expansion Factors

Temperature Increase

When the temperature of a liquid is increased, the liquid expands with a resulting increase in its volume.

Boyle's Law

This is stated in Boyle's Law, which concerns the relationship between pressure and volume in gases, i.e., $p_1V_1 = p_2V_2$.

Container Filling

Allowing an expansion space between the level of liquid and the top of the container requires filling LP-gas containers to a maximum of 80%.

Vapor Formation

Vapour forms above the liquid to fill the space left for expansion. The molecular movement of LP-gas vapours results in vapour pressure.

Liquid to Gas Expansion Ratios

1:600

Natural Gas

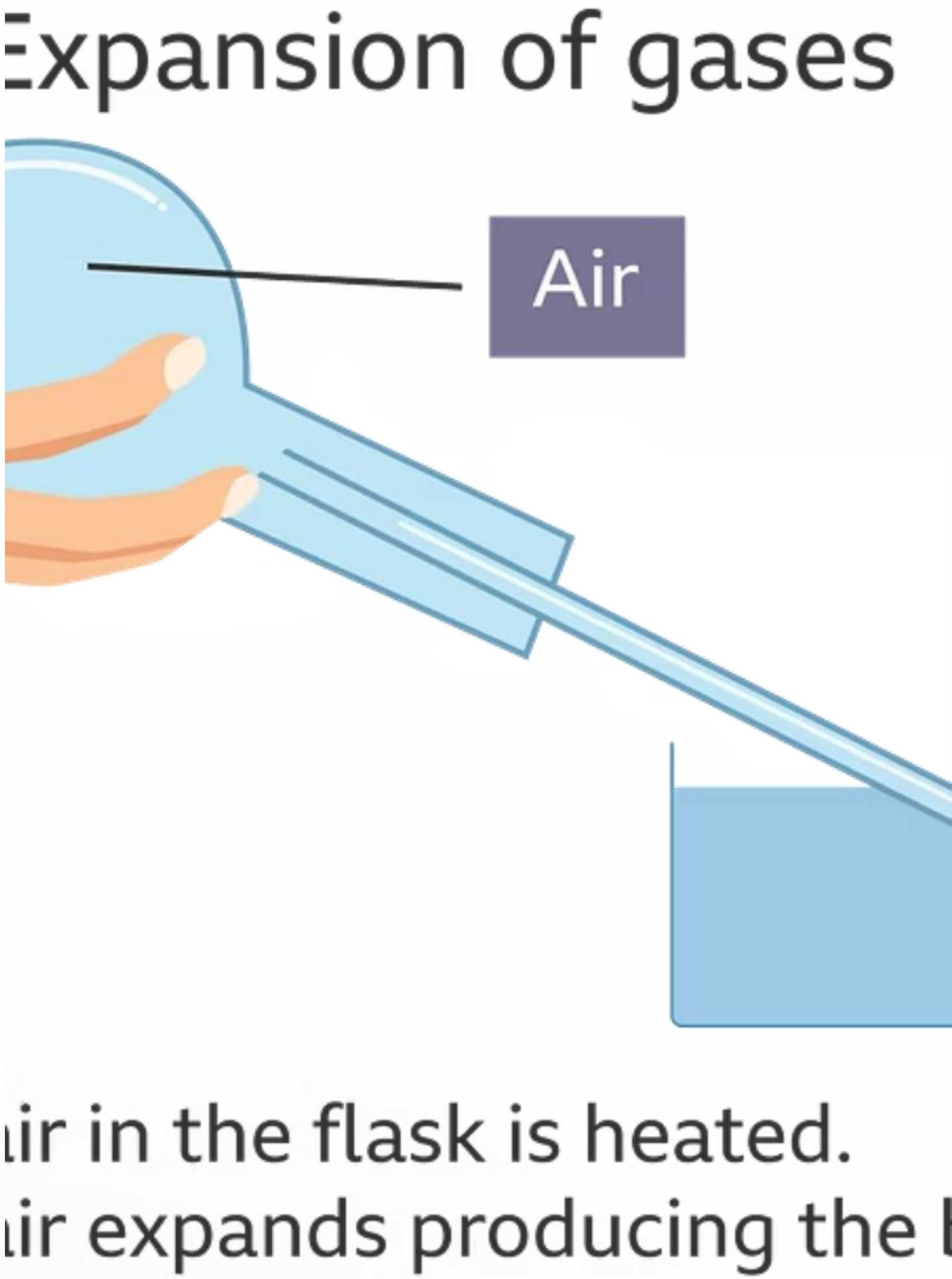
Expansion ratio of liquid to gas at atmospheric pressure

1:270

Propane

Expansion ratio of liquid to gas at atmospheric pressure

When a fuel changes from liquid to gas, a tremendous expansion takes place. This information can be useful when calculating the volume of vapour available from a volume of liquid fuel.



Boiling Points

Natural Gas

Natural gas has a boiling temperature of -260°F (-162.2°C) at atmospheric pressure.

A gas technician/fitter almost always handles natural gas in the gaseous state. (The utility company may, however, store liquefied natural gas for use during high demand periods.)

Propane

Propane has a boiling temperature of -44°F (-42.2°C) at atmospheric pressure.

Because LP-gas is subject to temperature changes, the temperature of the liquid determines the pressure in the container.

Temperature and Pressure Relationships

Temperature Increase

As the LP-gas temperature increases, so does the pressure increase in the storage tank

Pressure Increase

As the pressure is increased, the boiling temperature (saturation point) becomes progressively higher

Equilibrium

The liquid starts to vapourize to maintain the temperature-pressure relationship

Vapor Withdrawal

When vapour exhausts from the cylinder, the pressure drop causes the boiling temperature to drop

Important Pressure-Temperature Facts

Pressure and Fill Level

The pressure always varies with the temperature, not with the liquid content of the cylinder. For example, the pressure in a cylinder that is 30% full is the same as the pressure when it is 60% full.

Butane Limitations

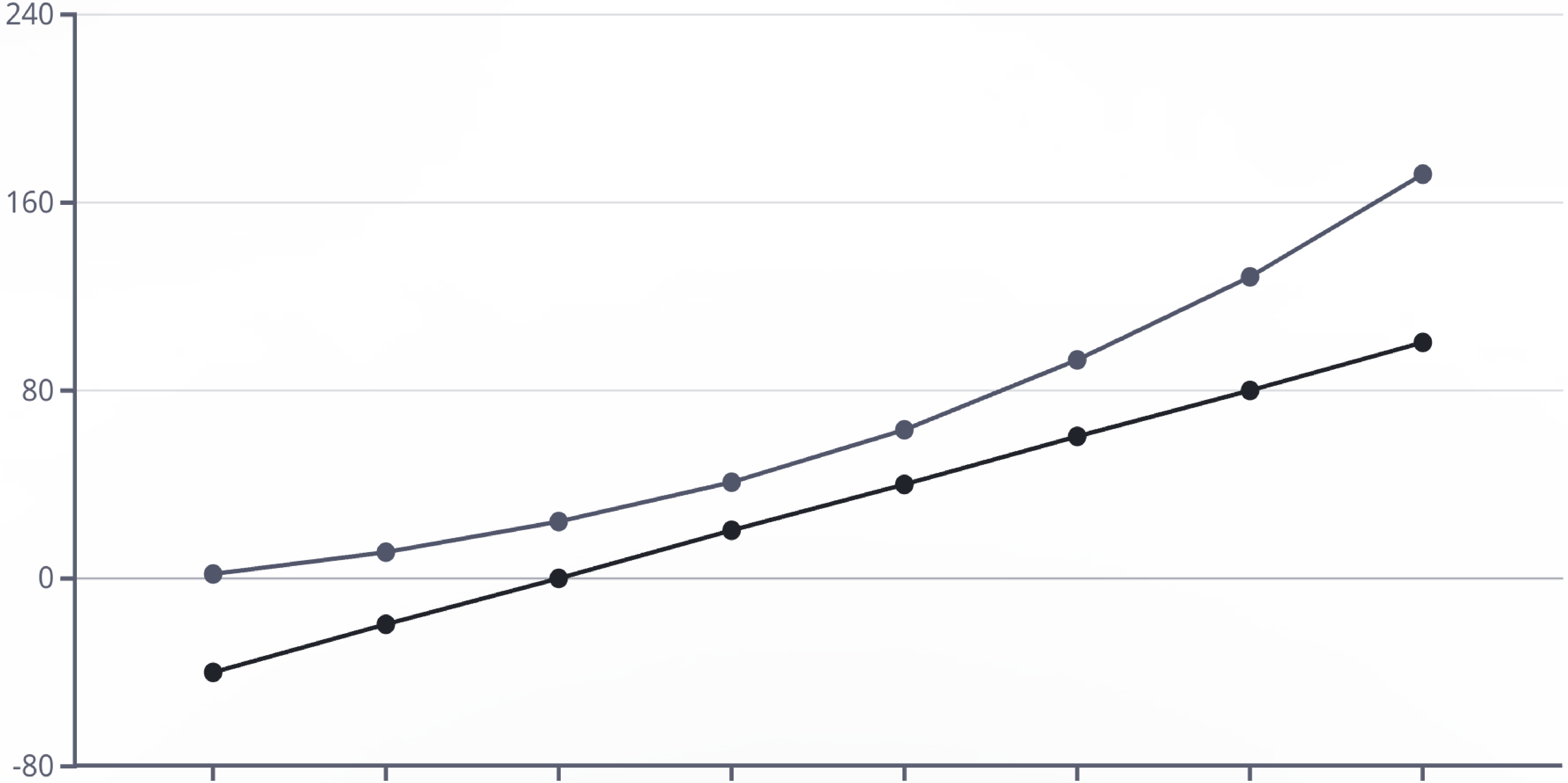
Note that butane has similar characteristics to propane. The biggest factor in the nonuse of butane in Canada is that its boiling temperature is 32°F (0°C). At that same temperature, butane has a vapour pressure of zero.

Pressure-Temperature Chart

Technicians use temperature-pressure relationship charts to predict the pressure in propane tanks at various temperatures.

p / MPa	ρ / $kg \cdot m^{-3}$	$100[(\rho_{sat} - \rho_{sat,EOS})/\rho_{sat,EOS}]$	T / K	p / MPa	ρ / $kg \cdot m^{-3}$	$100[(\rho_{sat}$
		first filling				
10.3474	487.109	0.0022	420.004	20.9309	389.393	
19.7839	485.644	0.0028	350.004	2.8452	70.633	
24.4560	484.992	0.0028	355.005	3.0033	73.459	
12.0702	449.429	0.0037	360.005	3.1083	73.436	
15.7612	448.822	0.0044	369.830	3.3094	73.366	
19.3751	448.260	0.0045	380.004	3.5135	73.336	
23.0986	447.703	0.0041	400.004	3.9018	73.217	
3.5062	392.664	0.0026	420.006	4.2440	72.251	
5.9494	392.139	0.0031	440.006	4.6131	72.240	
8.3824	391.643	0.0029	460.006	4.9788	72.265	
10.9194	391.154	0.0052	480.006	5.3405	72.283	
15.9263	390.230	0.0040	500.007	5.6977	72.281	
		second filling				
3.4364	96.262	0.0761	420.002	1.6390	22.775	
3.4680	96.380	0.1068	440.000	1.7332	22.750	
3.6756	100.803	−0.0274	460.002	1.8307	22.779	
3.8276	100.816	−0.0131	480.003	1.9250	22.771	
3.9802	100.464	0.0045	500.001	2.0168	22.738	
4.1320	100.514	−0.0003	310.004	0.7603	14.742	
4.6920	99.426	0.0155	315.004	0.7750	14.717	
5.2537	99.377	0.0175	320.003	0.7894	14.690	
5.8039	99.332	0.0163	325.004	0.8037	14.663	
6.3456	99.291	0.0140	330.003	0.8179	14.635	
6.8809	99.261	0.0106	340.002	0.8461	14.584	
7.4088	99.200	0.0079	360.005	0.9012	14.483	
2.3554	55.483	0.0982	369.854	0.9278	14.433	
2.4949	58.079	0.0008	380.004	0.9548	14.381	
2.5736	58.039	−0.0066	400.002	0.9590	13.553	
2.6507	57.995	−0.0051	420.002	0.9921	13.244	
2.7255	57.916	0.0033	440.005	1.0325	13.071	
2.8718	57.825	0.0198	460.005	1.0464	12.585	
3.0210	57.773	0.0204	480.006	1.0393	11.906	
3.3086	57.688	0.0229	500.006	1.0587	11.589	
3.5920	57.654	0.0155	310.004	0.4606	8.455	
3.8655	57.527	0.0042	320.003	0.4767	8.434	
4.1235	57.223	0.0002	330.003	0.4926	8.413	
4.3771	56.949	−0.0030	340.003	0.5083	8.392	
4.6444	56.938	−0.0090	360.004	0.5393	8.350	
1.7145	36.573	0.0837	369.854	0.5545	8.330	
1.7653	36.733	0.0735	380.003	0.5699	8.309	
1.8171	36.924	0.0686	400.004	0.6000	8.268	
1.9425	37.864	0.0440	420.006	0.6297	8.229	
2.0334	37.871	0.0553	440.006	0.6590	8.189	
2.1204	37.840	0.0557	460.006	0.6877	8.149	
2.2086	37.804	0.0508	480.004	0.7161	8.108	
2.3803	37.749	0.0443	500.006	0.7443	8.069	
2.5498	37.700	0.0127	310.003	0.2617	4.650	
2.7218	37.737	−0.0007	320.004	0.2702	4.640	
2.8925	37.772	−0.0078	330.004	0.2787	4.629	
3.0692	37.904	−0.0098	340.003	0.2871	4.619	
3.2435	38.005	−0.0043	360.000	0.3037	4.597	
1.3065	27.924	0.1017	369.852	0.3119	4.587	
1.3339	27.776	0.1500	380.002	0.3202	4.576	
1.3406	27.079	0.1103	400.003	0.3364	4.555	
1.3472	26.440	0.0431	420.002	0.3525	4.535	
1.3524	25.161	0.0454	440.002	0.3683	4.514	
1.3613	23.079	0.0408	460.005	0.3841	4.494	
1.3874	22.639	0.0447	480.006	0.3997	4.475	
1.4420	22.727	0.0407	500.005	0.4150	4.454	
1.5422	22.774	0.0333				

Propane Temperature-Pressure Relationship



Calorific Value (Heat Content)

Definition

The calorific value (heat content) of a fuel usually refers to the energy released during combustion of a given volume of fuel.

Units of Measurement

Generally, the units of measurement used are British Thermal Units per cubic foot (Btu/ft^3) or mega joules per cubic meter (MJ/m^3).

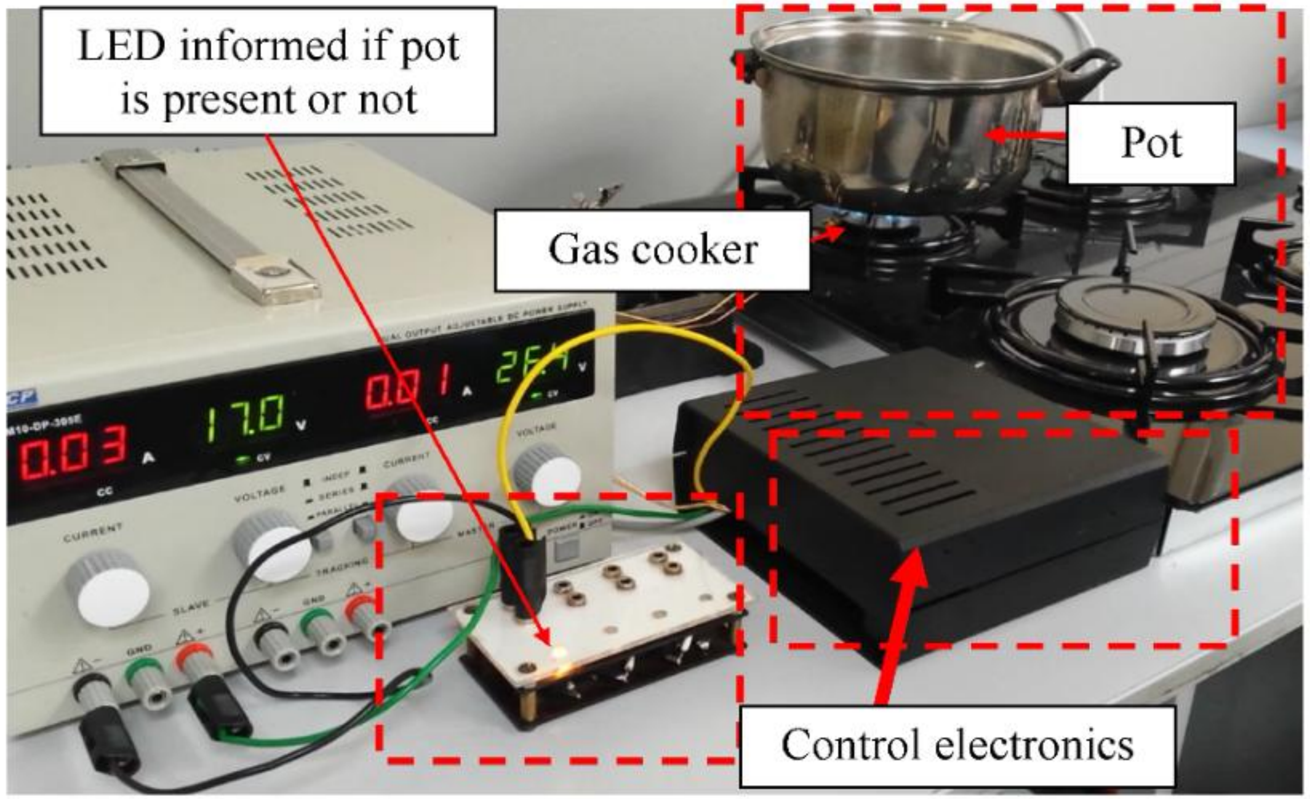
A Btu is the amount of heat required to raise the temperature of 1 lb of water 1°F.

Variability

The calorific value of natural gas varies from gas well because of the different components of natural gas.

Importance

You need to understand the calorific value of gases when calculating input rates to appliances.



Calorific Values of Common Fuel Gases

1,000

Natural Gas (Btu/ft^3)

Standard heat content measurement

10.35

Natural Gas (kW/m^3)

Metric equivalent for appliance ratings

2,520

Propane (Btu/ft^3)

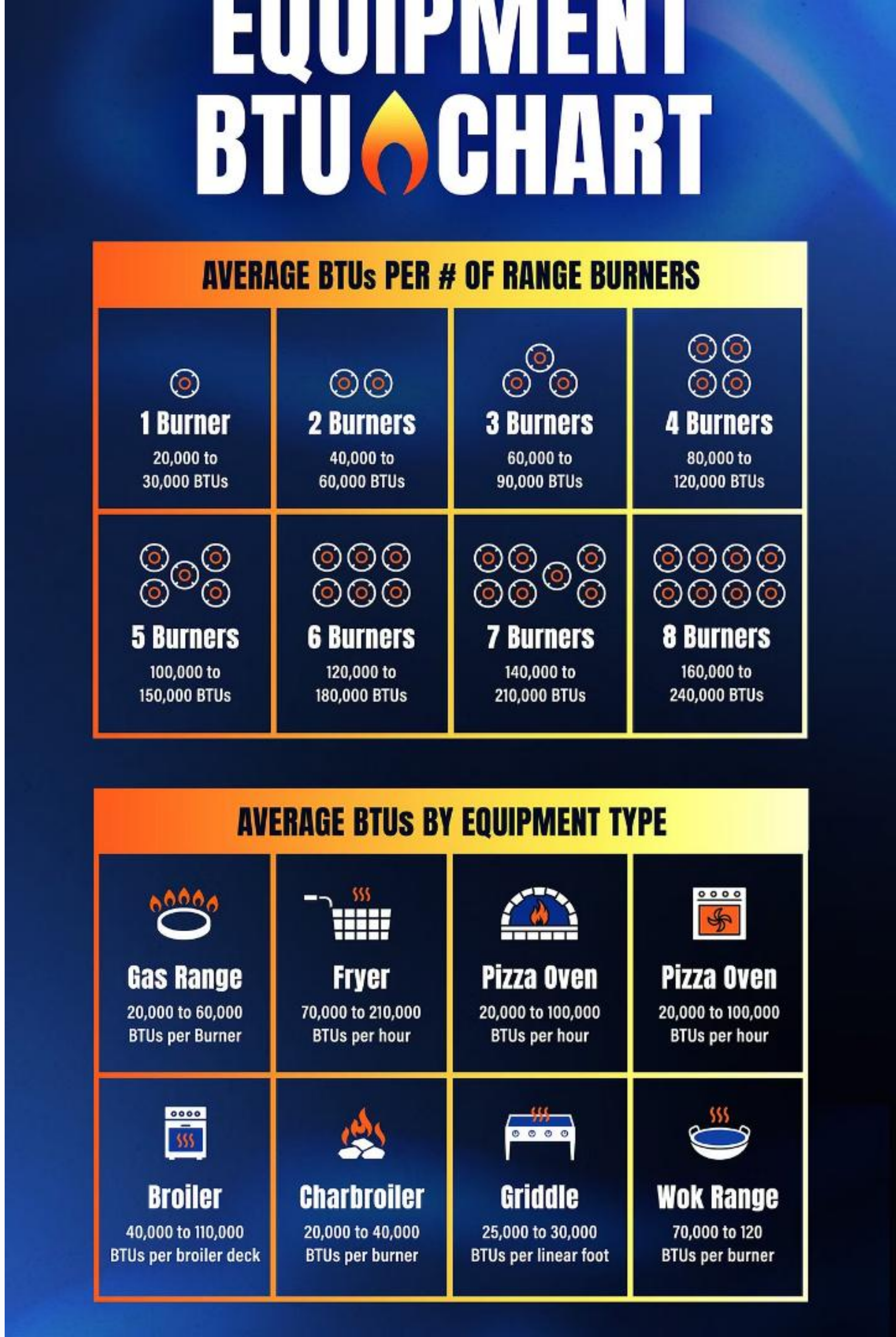
Higher heat content than natural gas

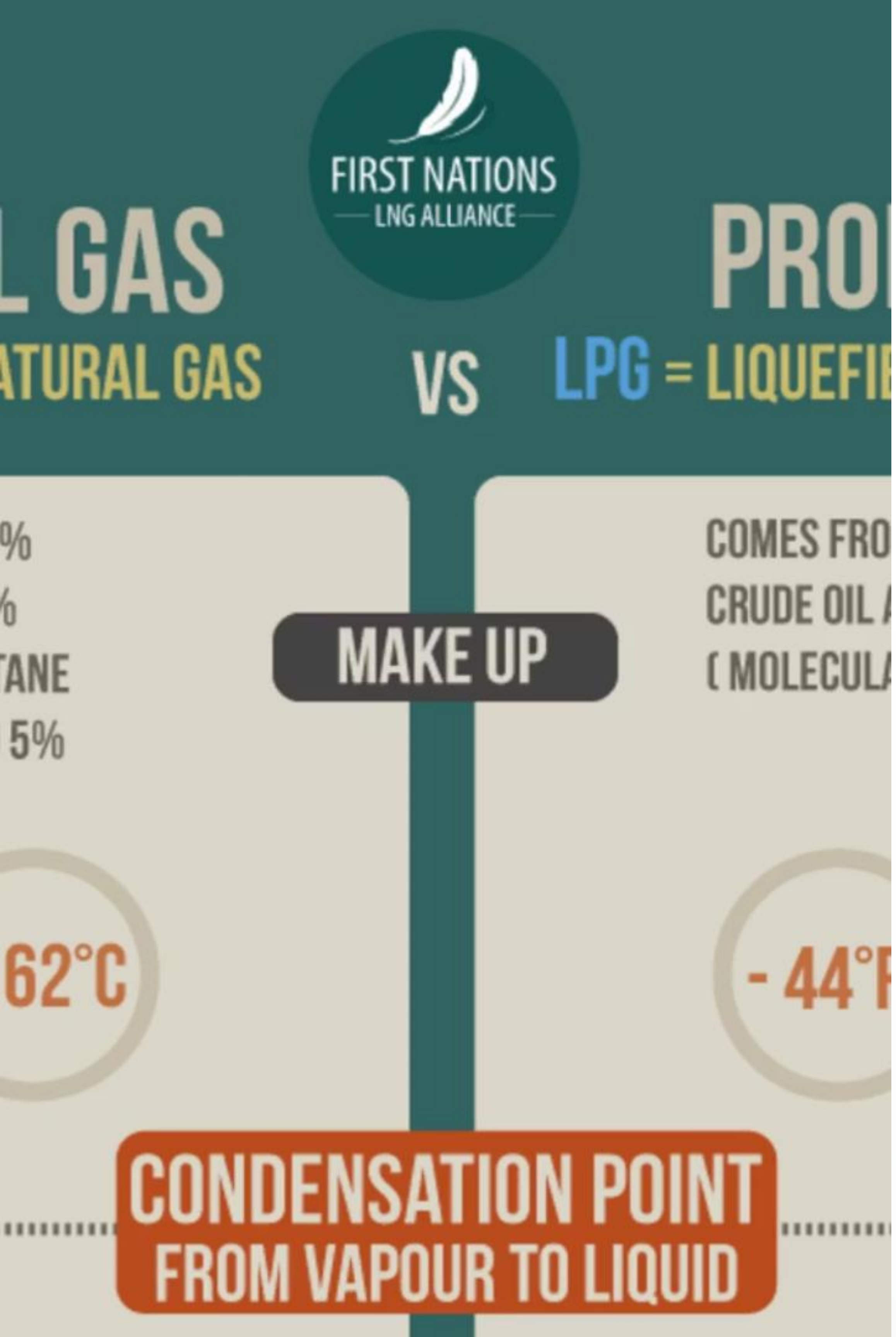
26

Propane (kW/m^3)

Metric equivalent for appliance ratings

The gas industry usually accepts these calorific values for natural gas and propane. For convenience when working with appliance input rates in kilowatts, you can express the metric calorific values in kW/m^3, as provided.



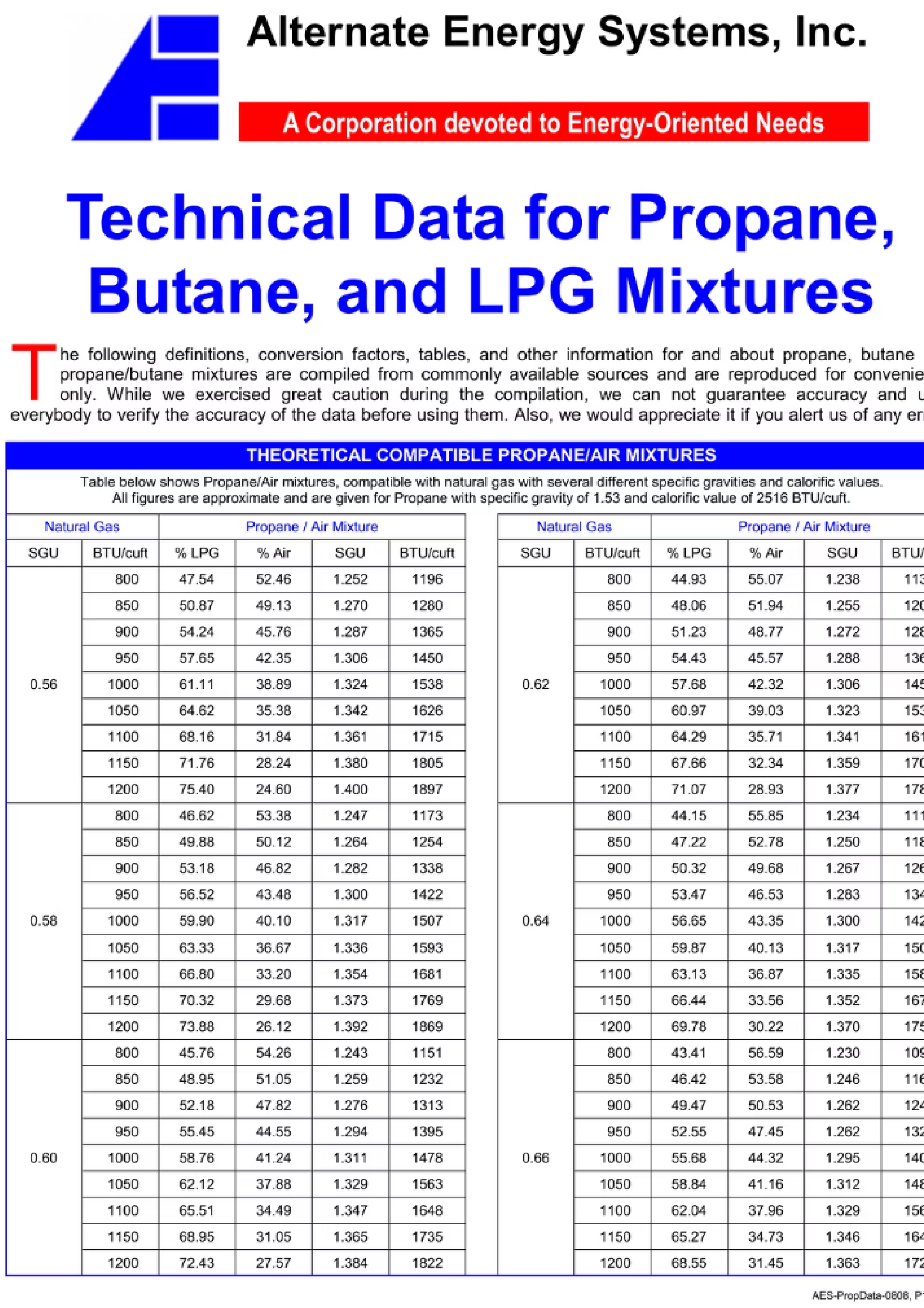


Summary of Properties

Properties	Natural gas	Propane
Formula designation	CH_4	C_3H_8
Toxicity	Nontoxic	Nontoxic
Physical properties	Colourless, tasteless, and odourless	Colourless, tasteless, and odourless
Odorant	Mercaptan	Mercaptan
Specific gravity (air = 1)	0.55	1.52

More Property Comparisons

Properties	Natural gas	Propane
Liquid weight	0.51	5.1 lb/imp gal
Expansion ratio (liquid to gas)	600 ft^3 (17 m^3)	270 ft^3 (7.6 m^3)
Boiling point	-260°F (-162°C)	-44°F (-42°C)
Calorific value	1,000 Btu/ft^3 (0.030 MJ/m^3) (10.35 kW/m^3)	2,520 Btu/ft^3 (0.075 MJ/m^3) (26 kW/m^3)



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Technical Data for Propane, Butane, and LPG Mixtures

The following definitions, conversion factors, tables, and other information for and about propane, butane propane/butane mixtures are compiled from commonly available sources and are reproduced for convenie only. While we exercised great caution during the compilation, we can not guarantee accuracy and u everybody to verify the accuracy of the data before using them. Also, we would appreciate it if you alert us of any er

THEORETICAL COMPATIBLE PROPANE/AIR MIXTURES

Table below shows Propane/Air mixtures, compatible with natural gas with several different specific gravities and calorific values. All figures are approximate and are given for Propane with specific gravity of 1.53 and calorific value of 2516 BTU/cuft.

Natural Gas		Propane / Air Mixture			
SGU	BTU/cuft	% LPG	% Air	SGU	BTU/cuft
0.56	800	47.54	52.46	1.252	1196
	850	50.87	49.13	1.270	1280
	900	54.24	45.76	1.287	1365
	950	57.65	42.35	1.306	1450
	1000	61.11	38.89	1.324	1538
	1050	64.62	35.38	1.342	1626
	1100	68.16	31.84	1.361	1715
	1150	71.76	28.24	1.380	1805
	1200	75.40	24.60	1.400	1897
0.58	800	46.62	53.38	1.247	1173
	850	49.88	50.12	1.264	1254
	900	53.18	46.82	1.282	1338
	950	56.52	43.48	1.300	1422
	1000	59.90	40.10	1.317	1507
	1050	63.33	36.67	1.336	1593
	1100	66.80	33.20	1.354	1681
	1150	70.32	29.68	1.373	1769
	1200	73.88	26.12	1.392	1869
0.60	800	45.76	54.26	1.243	1151
	850	48.95	51.05	1.259	1232
	900	52.18	47.82	1.276	1313
	950	55.45	44.55	1.294	1395
	1000	58.76	41.24	1.311	1478
	1050	62.12	37.88	1.329	1563
	1100	65.51	34.49	1.347	1648
	1150	68.95	31.05	1.365	1735
	1200	72.43	27.57	1.384	1822

Natural Gas		Propane / Air Mixture			
SGU	BTU/cuft	% LPG	% Air	SGU	BTU/
0.62	800	44.93	55.07	1.238	113
	850	48.06	51.94	1.255	120
	900	51.23	48.77	1.272	128
	950	54.43	45.57	1.288	136
	1000	57.68	42.32	1.306	145
	1050	60.97	39.03	1.323	153
	1100	64.29	35.71	1.341	161
	1150	67.66	32.34	1.359	170
	1200	71.07	28.93	1.377	178
0.64	800	44.15	55.85	1.234	111
	850	47.22	52.78	1.250	118
	900	50.32	49.68	1.267	126
	950	53.47	46.53	1.283	134
	1000	56.65	43.35	1.300	142
	1050	59.87	40.13	1.317	150
	1100	63.13	36.87	1.335	158
	1150	66.44	33.56	1.352	167
	1200	69.78	30.22	1.370	175
0.66	800	43.41	56.59	1.230	109
	850	46.42	53.58	1.246	116
	900	49.47	50.53	1.262	124
	950	52.55	47.45	1.262	132
	1000	55.68	44.32	1.295	140
	1050	58.84	41.16	1.312	148
	1100	62.04	37.96	1.329	156
	1150	65.27	34.73	1.346	164
	1200	68.55	31.45	1.363	172

AES-PropData-0808, P

Combustion Data

In this section, you identify combustion data related to the physical properties of natural gas and propane.

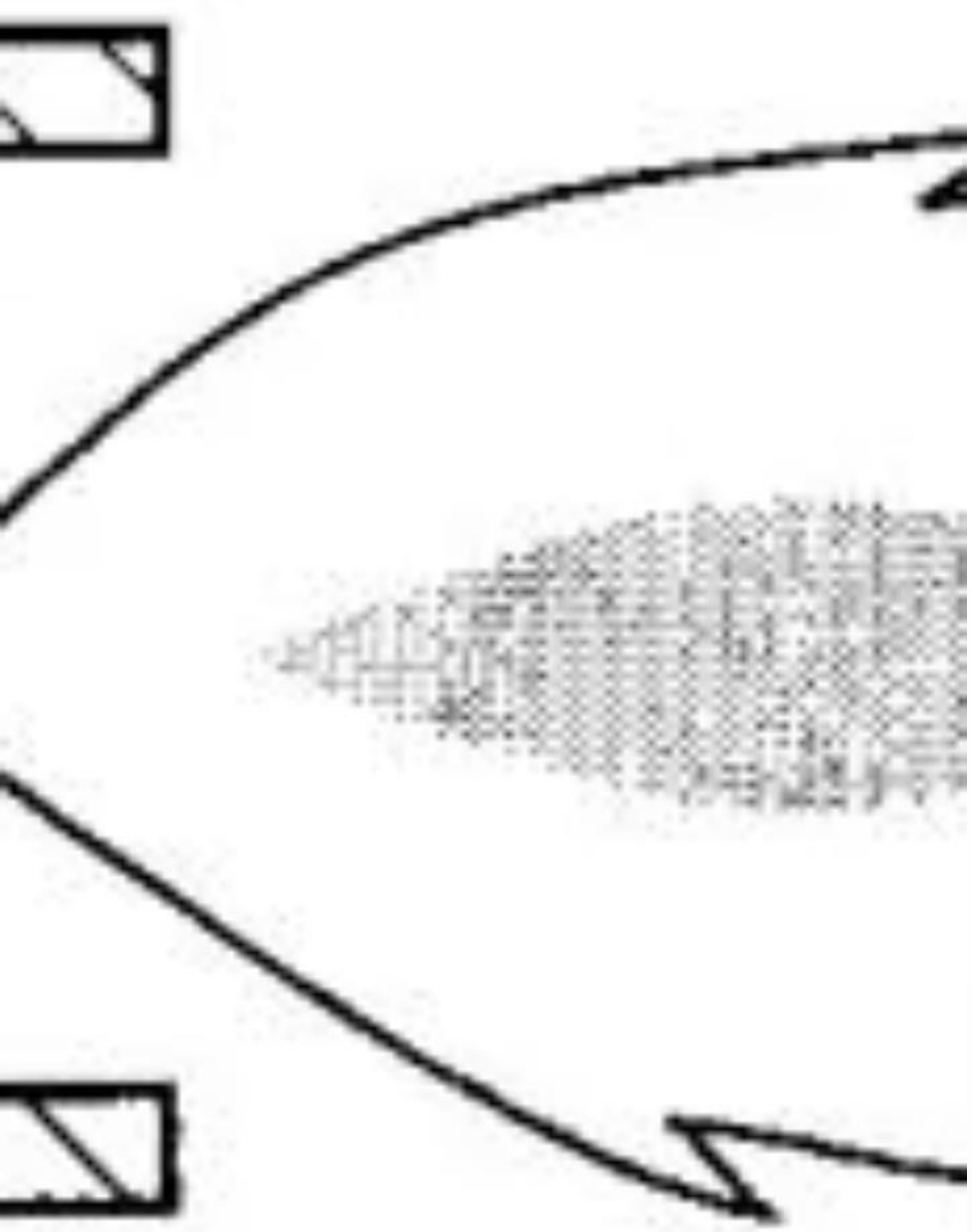
Limits of Flammability

Limits of flammability are the upper and lower ranges of gas in the air-gas mixture that supports combustion. You must know these limits in order to supply the correct amount of air to gas burners or troubleshoot burner problems. Also, knowing the limits of flammability is key to responding to a gas leakage call.

The lower flammable limit is the weakest air-gas mixture that burns. The upper limit is the strongest air-gas mix that produces and sustains combustion. Too low an amount of fuel makes the mixture "lean." Too high an amount of fuel renders the mix too "rich."

Ignition Temperature

Ignition temperature is the temperature at which an air-gas mixture initiates and supports combustion. It varies according to the fuel gas used.



More Combustion Data

Flame Temperature

You can only reach maximum flame temperature at perfect combustion, which is the theoretical point at which combustion may occur. In practice, the gas technician/fitter provides excess air to provide enough oxygen to ensure the complete combustion of the fuel. Each fuel gas has its own maximum flame temperature.

Flame Speed

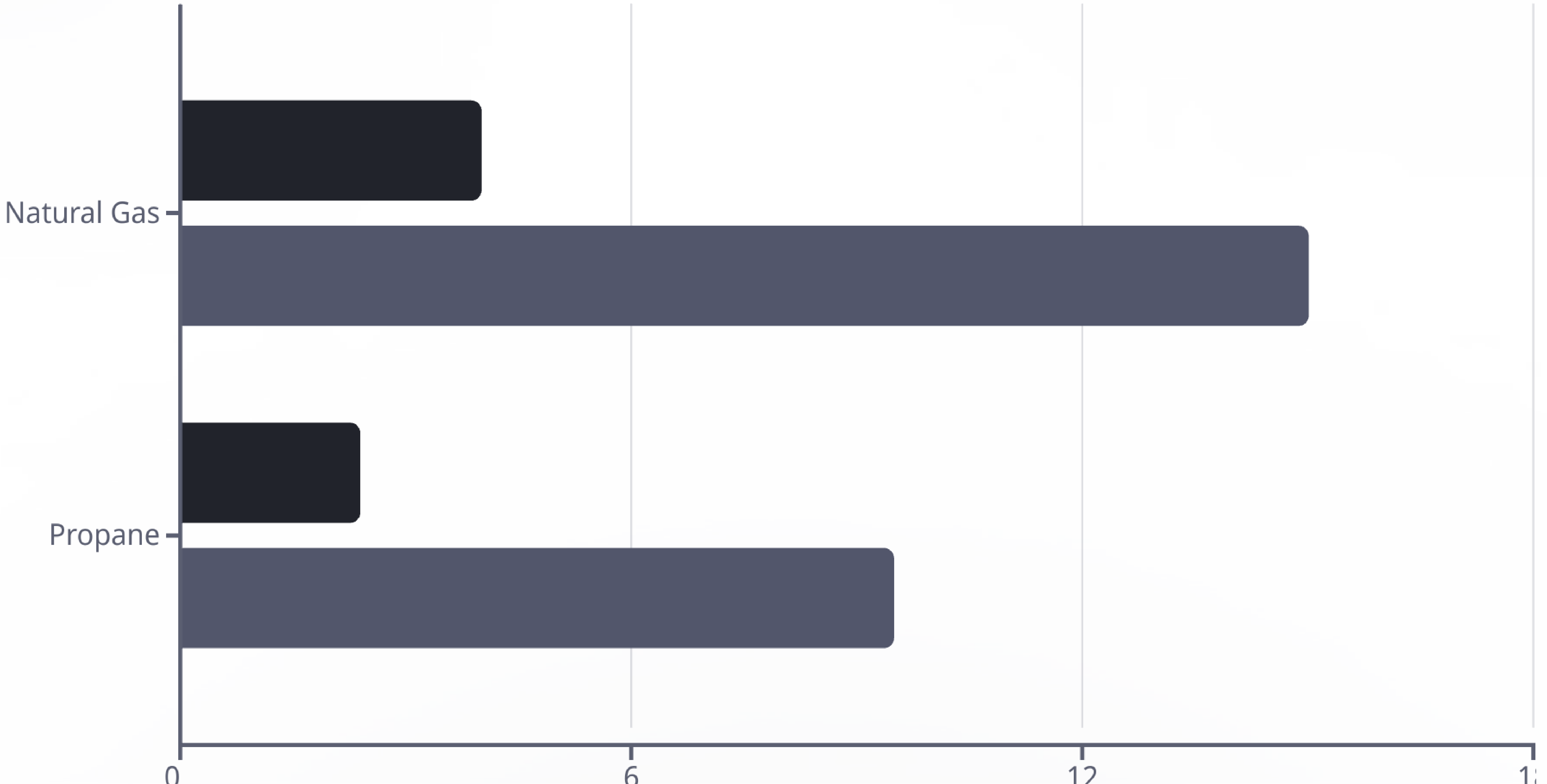
Flame speed is the speed at which the flame front moves towards the air-gas mixture issuing from the burner port. Flame speed depends on the quantity of air in the air-gas mixture and the type of gas you are using.

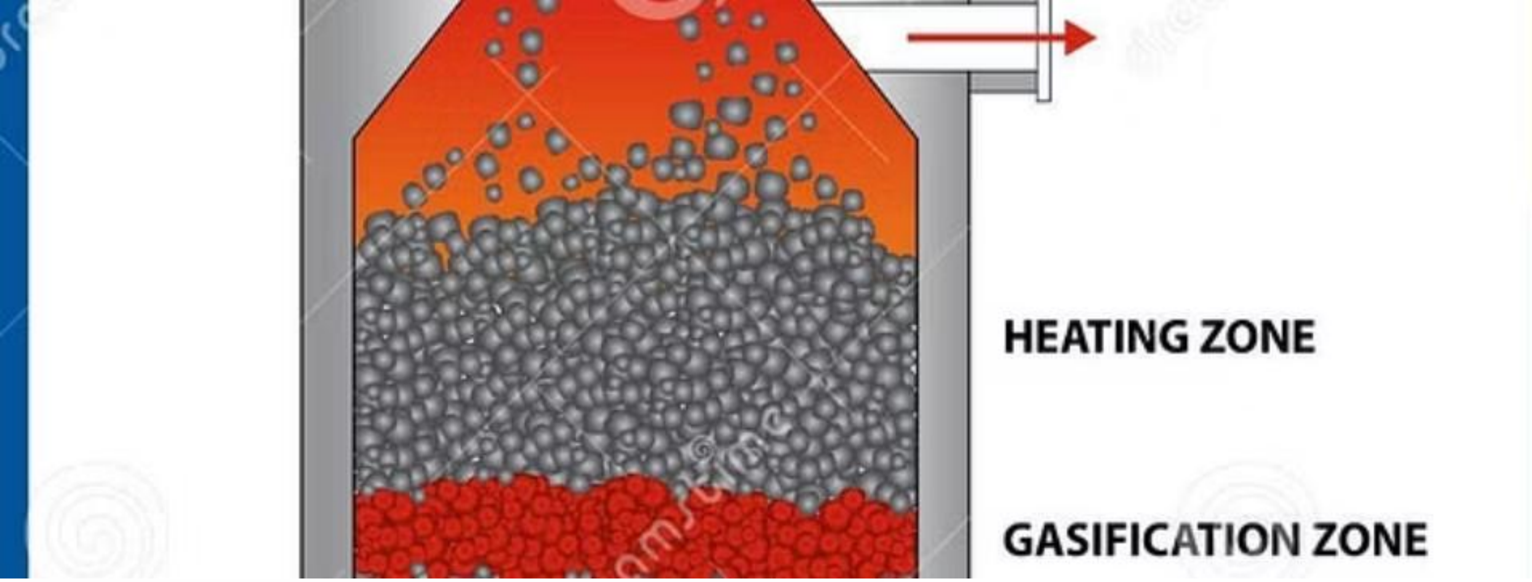
Combustion Data Summary

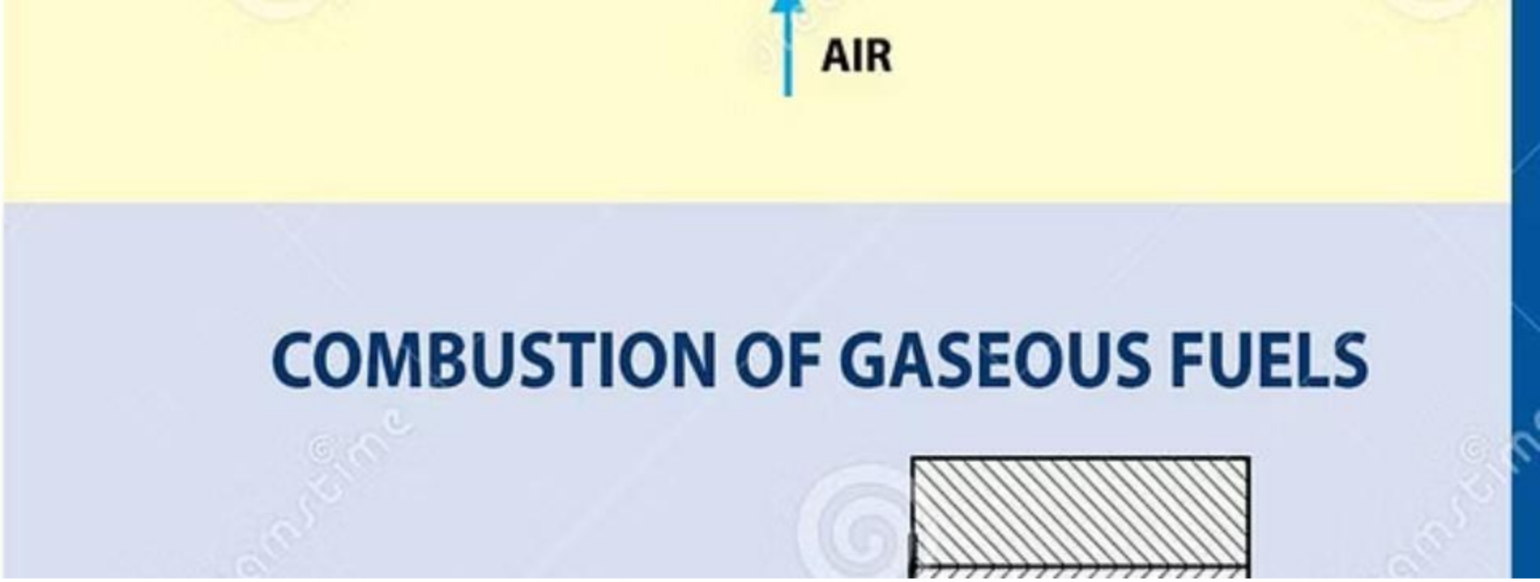
Item	Natural gas	Propane
Limits of flammability	4-15%	2.4-9.5%
Ignition temperature	1,300°F (700°C)	920°F (495°C)
Maximum flame temperature	3,600°F (1,980°C)	3,600°F (1,980°C)
Flame speed*	12 in/s (305 mm/s)	11 in/s (280 mm/s)

*Approximate flame speed based on Bunsen-type burner test method.

Limits of Flammability







Ignition Temperatures

1,300°F

Natural Gas

700°C ignition temperature

920°F

Propane

495°C ignition temperature

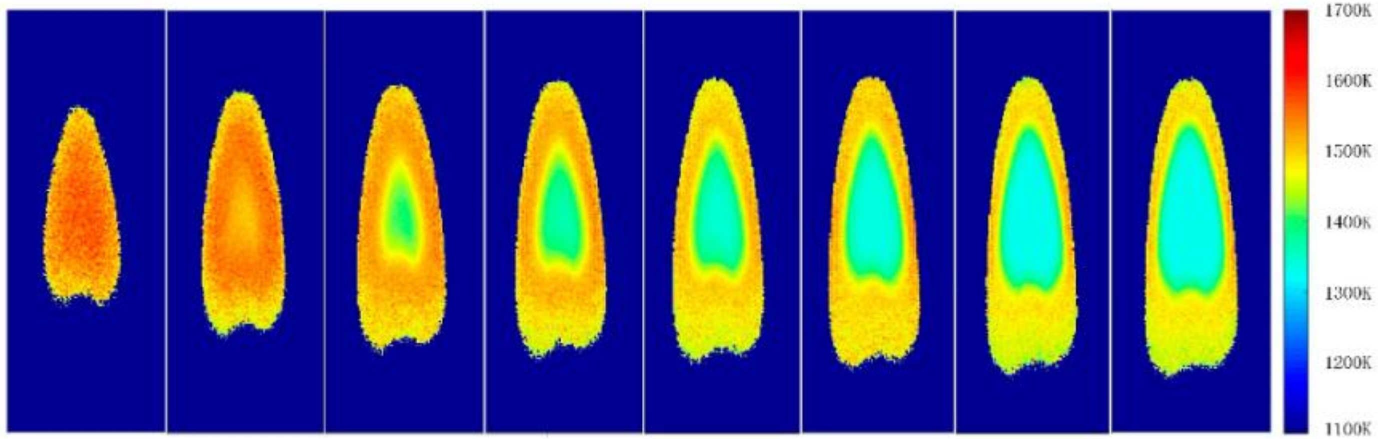
The ignition temperature is the minimum temperature required for the gas to ignite when mixed with the proper amount of air. Note that propane has a significantly lower ignition temperature than natural gas, making it more easily ignitable in certain conditions.

Flame Temperature and Speed

Maximum Flame Temperature

Both natural gas and propane have a maximum flame temperature of 3,600°F (1,980°C) under perfect combustion conditions.

In practice, the gas technician/fitter provides excess air to ensure complete combustion of the fuel, which slightly reduces the actual flame temperature.

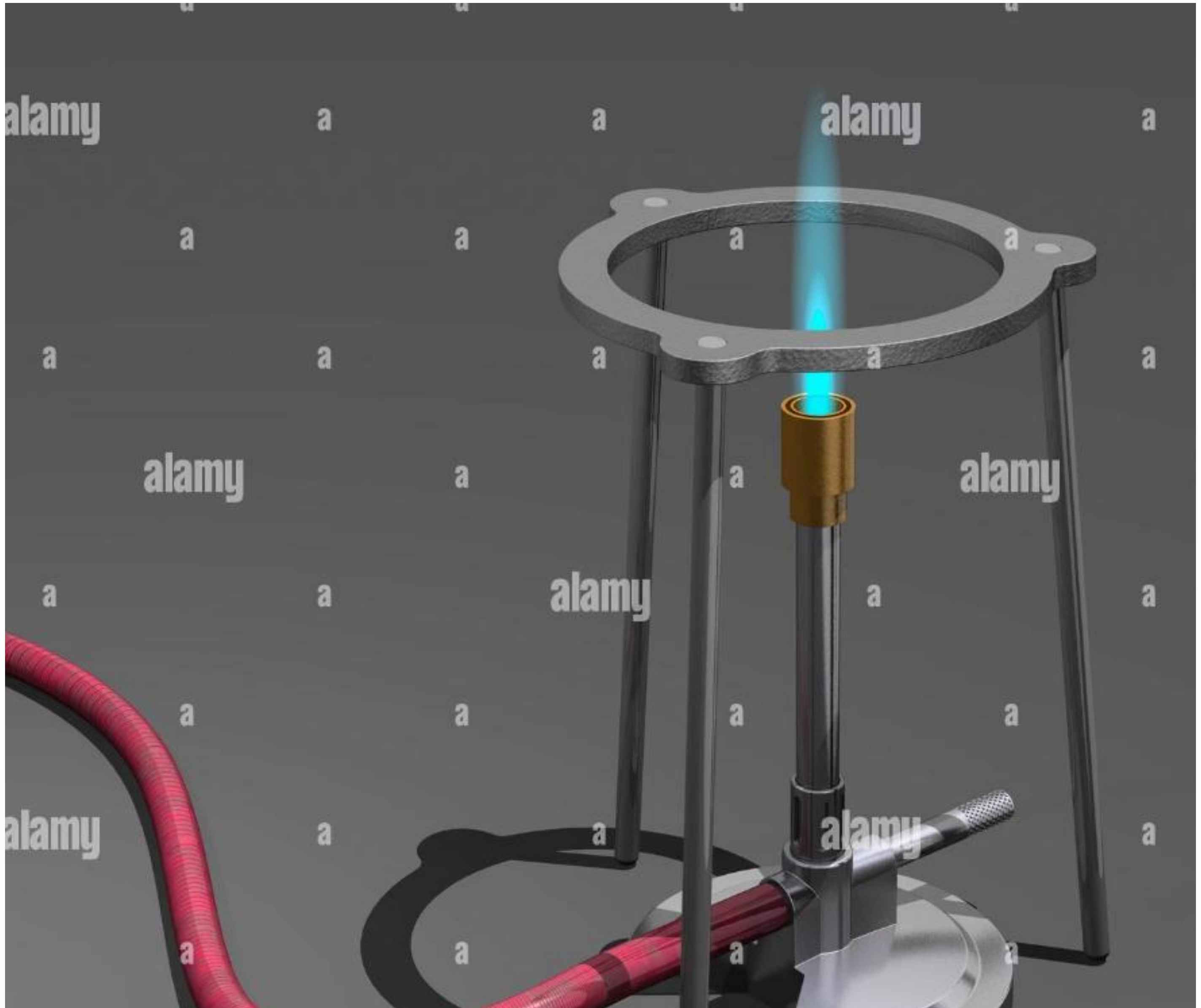


Flame Speed

Natural gas has a flame speed of approximately 12 in/s (305 mm/s).

Propane has a slightly slower flame speed of approximately 11 in/s (280 mm/s).

These measurements are based on a Bunsen-type burner test method and can vary based on the air-gas mixture ratio.



Importance of Combustion Data

Appliance Adjustment

Understanding combustion data allows technicians to properly adjust gas appliances for optimal performance and safety.

Troubleshooting

Knowledge of flame characteristics helps identify problems with gas appliances and systems.

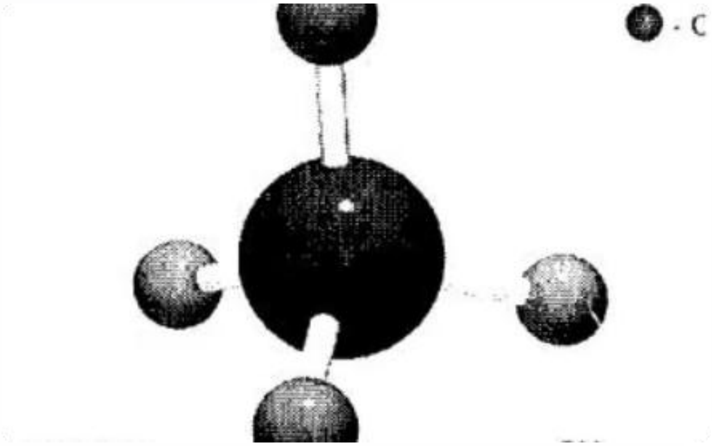
Safety Procedures

Awareness of flammability limits and ignition temperatures is crucial when responding to gas leaks.

System Design

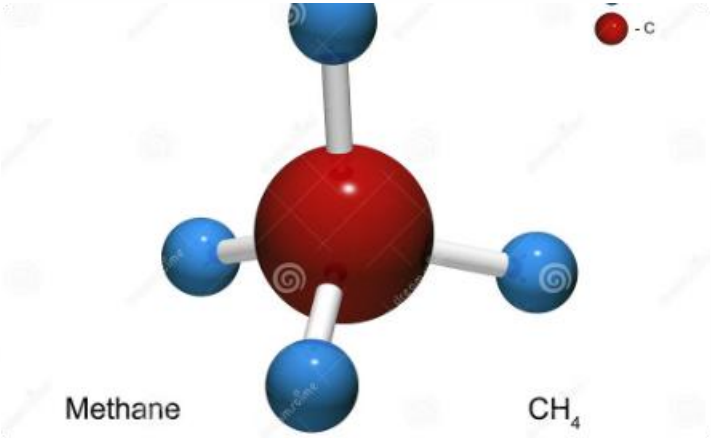
Combustion data informs the proper design of gas systems and selection of components.

Methane Molecule Structure



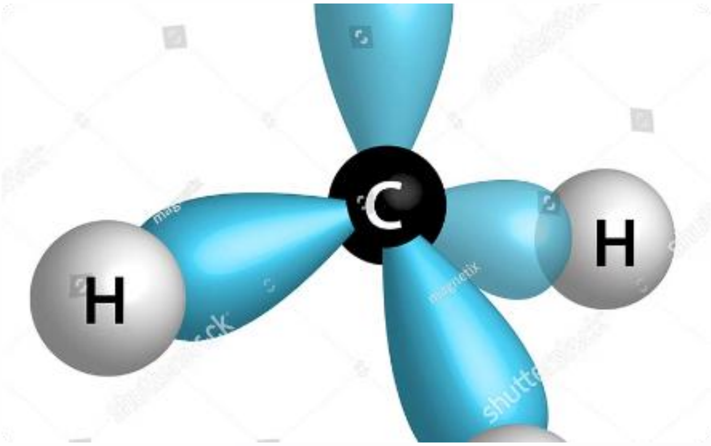
Tetrahedral Structure

The methane molecule (CH_4) has a tetrahedral structure with the carbon atom at the center and four hydrogen atoms at the corners.



Bond Angles

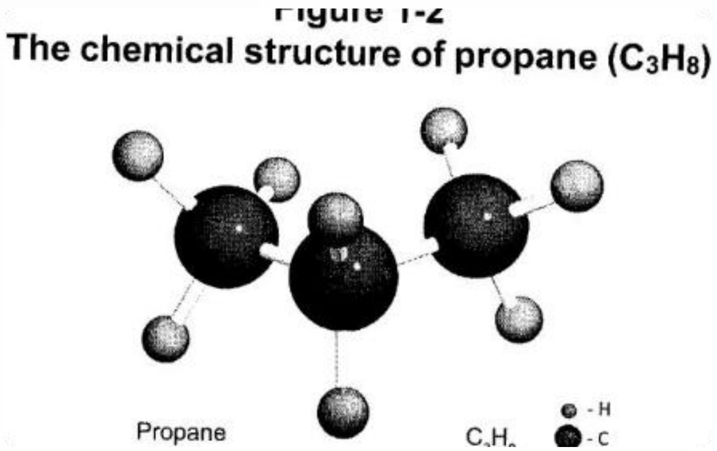
The bond angles between hydrogen atoms in methane are approximately 109.5 degrees, creating a stable, symmetrical structure.



Chemical Stability

This structure makes methane the most stable of the hydrocarbon molecules, allowing it to exist unchanged at temperatures up to 1022°F (550°C).

Propane Molecule Structure

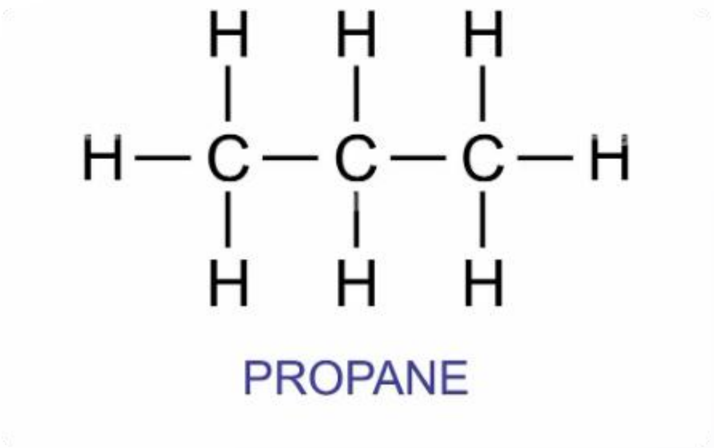


Linear Carbon Chain

Propane (C_3H_8) consists of three carbon atoms in a chain with eight hydrogen atoms attached.

Molecular Structure

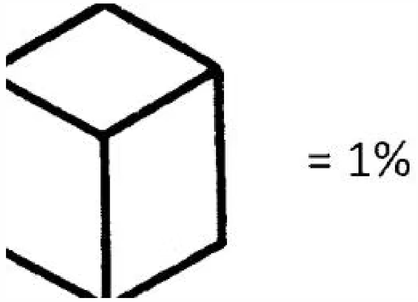
The carbon atoms form a zigzag pattern rather than a straight line, with hydrogen atoms arranged around them.



Chemical Bonds

Propane features single covalent bonds between all atoms, making it relatively stable but more reactive than methane.

Odorization of Fuel Gases



Mercaptan Addition

Since natural gas and propane are naturally odorless, mercaptan is added as a safety measure to make leaks detectable by smell.

Detection Standard

The odorant concentration must be sufficient to be readily detectable when the fuel gas concentration equals 1% of room volume.

Chemical Formula

The chemical formula for ethyl mercaptan typically used in natural gas is C_2H_5S.

Concentration

To detect a gas leak below its lower flammable limit, every one million cubic feet of gas should have approximately one pound of mercaptan.

Natural Gas Production and Processing

Extraction

Natural gas is extracted from underground reservoirs, often alongside petroleum deposits or from dedicated gas fields.

Processing

Raw natural gas undergoes processing to remove impurities, water, and heavier hydrocarbons like propane and butane.

Odorization

Mercaptan is added to give the gas its characteristic smell for safety purposes.

Distribution

The processed gas is transported through pipelines to distribution centers and ultimately to end users.

Propane Production and Processing

Extraction

Propane is extracted as a component of natural gas processing or as a byproduct of petroleum refining.

Separation

It is separated from other hydrocarbons through a process called fractionation, which uses different boiling points to isolate specific compounds.

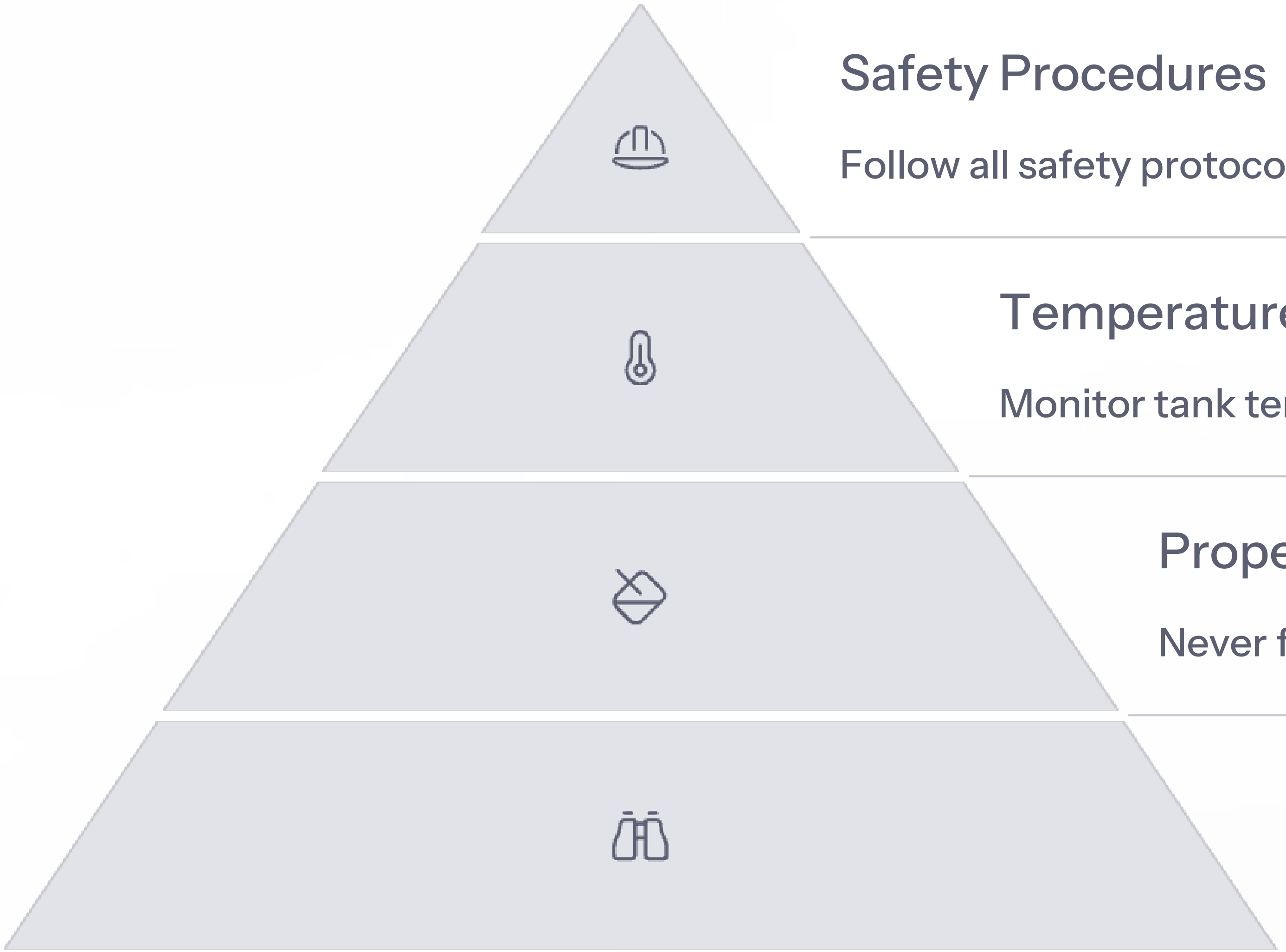
Liquefaction

The propane is compressed and cooled to convert it to a liquid state for easier storage and transport.

Distribution

Liquefied propane is transported in pressurized tanks to distribution centers and then to end users in smaller cylinders or tanks.

Propane Storage and Handling



Safety Procedures

Follow all safety protocols for handling pressurized gas

Temperature Monitoring

Monitor tank temperature to prevent excessive pressure

Proper Fill Levels

Never fill tanks beyond 80% capacity

Regular Inspection

Check tanks and connections for leaks and damage

Proper storage and handling of propane is essential for safety. Propane is stored as a liquid under pressure, and tanks must never be filled beyond 80% capacity to allow for thermal expansion. Regular inspection of tanks, valves, and connections is necessary to prevent leaks.

Natural Gas Safety Considerations

Detect odors

Be alert to the smell of mercaptan

Ensure ventilation

Provide adequate air for combustion

Proper installation

Follow all codes and standards

Regular inspection

Check equipment and connections

Natural gas is lighter than air, so leaks will rise and collect near ceilings. This property affects how technicians should approach leak detection and ventilation strategies. Despite being non-toxic, natural gas can cause asphyxiation by displacing oxygen in enclosed spaces.

Propane Safety Considerations

Detect odors

Be alert to the smell of mercaptan

Check low areas

Propane is heavier than air

Monitor temperature

Prevent excessive pressure

Proper installation

Follow all codes and standards

Propane is heavier than air, so leaks will sink and collect in low areas like basements, crawl spaces, and ditches. This property significantly affects how technicians should approach leak detection and ventilation strategies. Special attention must be paid to low-lying areas when checking for propane leaks.

Boyle's Law and Gas Behavior

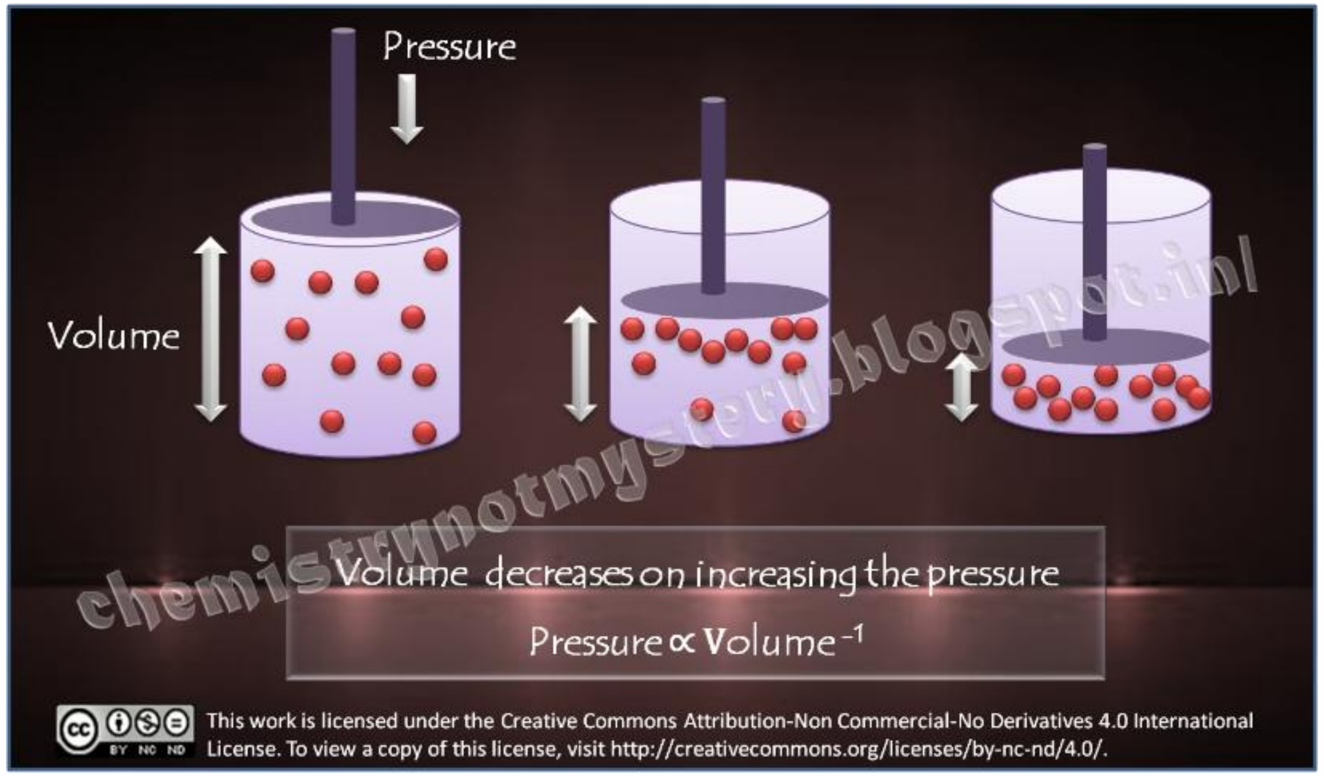
Boyle's Law Formula

$p_1V_1 = p_2V_2$

This equation states that the absolute pressure that a given mass of an ideal gas exerts is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.

Practical Applications

- Understanding pressure changes in gas lines
- Calculating volume changes in storage tanks
- Designing pressure regulators



When the volume of a gas decreases, its pressure increases proportionally, assuming temperature remains constant. This principle is fundamental to understanding how gases behave in closed systems like propane tanks and gas lines.

Vapor Pressure in LP-Gas Containers

Temperature Effect

Vapor pressure is directly related to the temperature of the liquid in an enclosed container

Below Boiling Point

If the temperature of a fuel gas is lower than its boiling point, it will not vaporize, and no vapor pressure will develop

Increasing Temperature

As the LP-gas temperature increases, so does the pressure increase in the storage tank

Pressure Equilibrium

The pressure always varies with the temperature, not with the liquid content of the cylinder

Calculating Gas Input Rates

Importance of Calorific Value

Understanding the calorific value (heat content) of gases is essential when calculating input rates to appliances.

Input Rate Formula

Input Rate (Btu/h) = Volume Flow Rate (ft^3/h) × Calorific Value (Btu/ft^3)

Metric Calculation

Input Rate (kW) = Volume Flow Rate (m^3/h) × Calorific Value (kW/m^3)

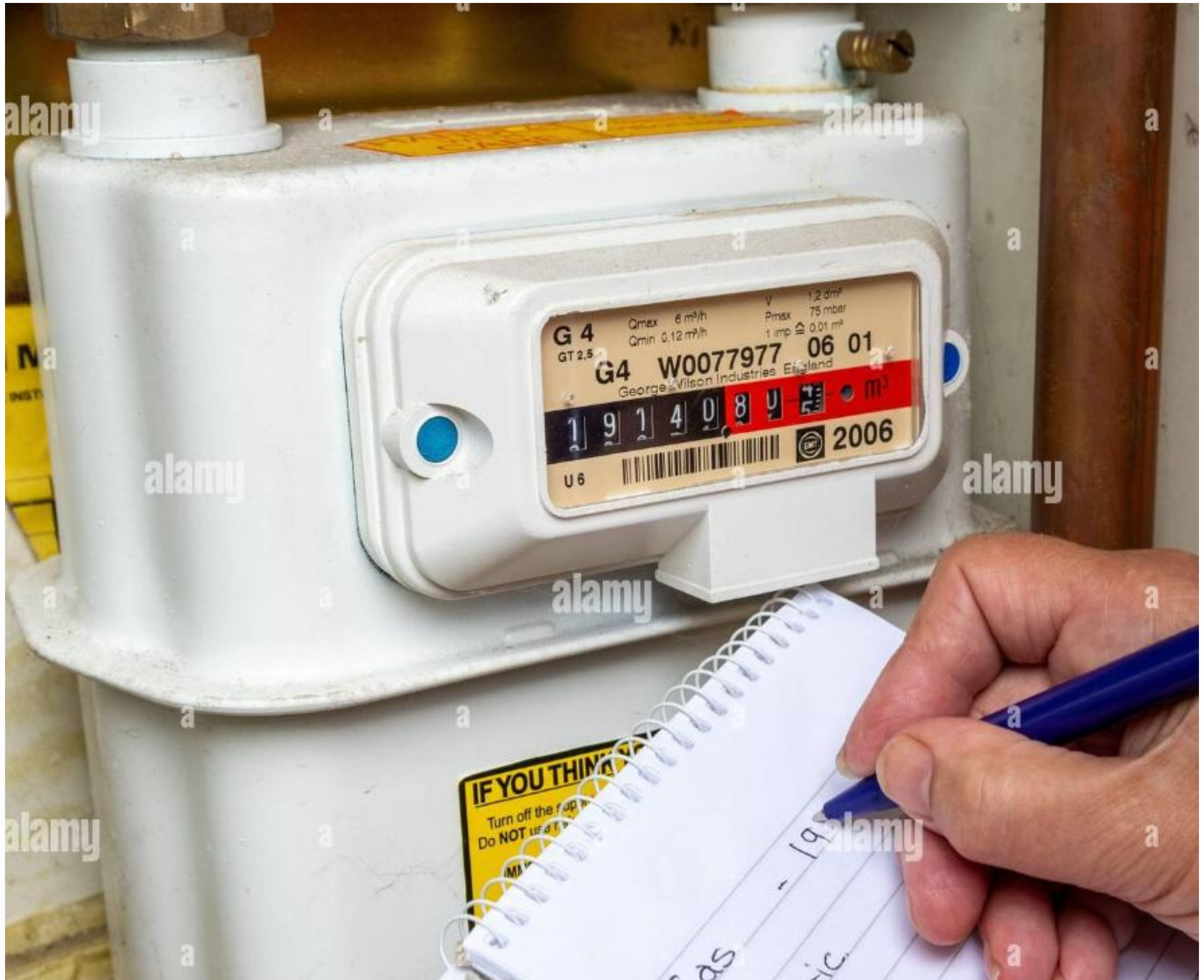
Example Calculation

For a natural gas appliance with a flow rate of 2 m^3/h:

Input Rate = 2 m^3/h × 10.35 kW/m^3 = 20.7 kW

For Propane

The same calculation using propane's higher calorific value would yield a much higher input rate, which is why orifice sizes must be adjusted when converting appliances between fuel types.



Flame Characteristics

Perfect Combustion

A properly adjusted gas flame has a clear blue color with well-defined inner and outer cones. This indicates complete combustion with the right air-gas mixture.

Incomplete Combustion

Yellow flames indicate incomplete combustion, often due to insufficient primary air. This can lead to carbon monoxide production and should be corrected immediately.

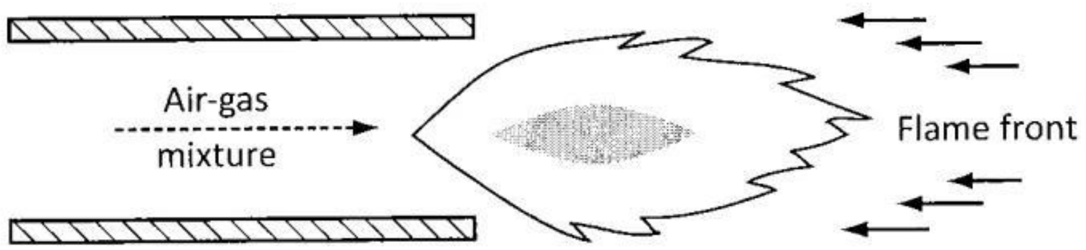
Flame Lifting

When flames lift away from the burner ports, it indicates too much primary air or excessive gas pressure. This condition can lead to flame extinction and gas leakage.

Flame Speed and Burner Design

Flame Speed Definition

Flame speed is the speed at which the flame front moves towards the air-gas mixture issuing from the burner port.



Factors Affecting Flame Speed

- Type of gas (natural gas vs. propane)
- Air-gas mixture ratio
- Temperature of the mixture
- Burner port design

Importance in Burner Design

Burners must be designed so that the gas flow velocity from the ports is slightly higher than the flame speed to prevent flashback (flame traveling back into the burner).

Gas Leak Detection

Smell Test

The first indication of a gas leak is often the smell of mercaptan, the odorant added to natural gas and propane.

Soap Solution Test

Apply a soap solution to suspected leak areas. Bubbles will form where gas is escaping.

Electronic Detection

Use electronic gas detectors calibrated for the specific gas being tested.

Systematic Inspection

Check all joints, connections, and potential leak points in a methodical manner.

Responding to Gas Leaks

Evacuate the Area

If a significant leak is detected, ensure everyone leaves the building immediately.

Call for Help

Contact emergency services and the gas utility from a safe location.

Avoid Ignition Sources

Do not operate electrical switches, use phones, or create any sparks in the affected area.

Ventilate if Safe

If it's safe to do so, open doors and windows to allow gas to dissipate.

Shut Off Gas

If possible and safe, turn off the main gas supply valve.

Sizing Gas Piping Systems

Factors to Consider

- Type of gas (natural gas or propane)
- Specific gravity of the gas
- Length of pipe run
- Number of fittings
- Total gas load (BTU/hr)
- Allowable pressure drop

Importance of Proper Sizing

Properly sized gas piping ensures that all appliances receive adequate gas supply at the correct pressure, even when all appliances are operating simultaneously.

Undersized piping can lead to insufficient gas flow, poor appliance performance, and potentially dangerous operating conditions.

GAS PIPE SIZING CHART

NATURAL GAS

PIPE LENGTH (feet)	1/2"	3/4"	1"	1 - 1/4"	1 - 1/2"	2"	2 - 2 1/2"	3"	4"
10	108	230	387	793	1237	2259	3640	6434	-
20	75	160	280	569	877	1610	2613	5236	9521
30	61	129	224	471	719	1335	2165	4107	7859
40	52	110	196	401	635	1143	1867	3258	6795
50	46	98	177	364	560	1041	1680	2936	6142
60	42	89	159	336	513	957	1559	2684	5647
70	38	82	149	317	476	896	1447	2492	5250
80	36	76	140	239	443	840	1353	2315	4900
90	33	71	133	275	420	793	1288	2203	4667
100	32	68	126	266	411	775	1246	2128	4518
125	28	60	117	243	369	700	1143	1904	4065
150	25	54	105	215	327	625	1008	1689	3645
175	23	50	93	196	303	583	993	1554	3370
200	22	47	84	182	280	541	877	1437	3160
300	17	37	70	145	224	439	686	1139	2539

Natural Gas (NG) flow is given in thousands of BTU/hr. One cubic foot of NG gas - 1000 BTU.

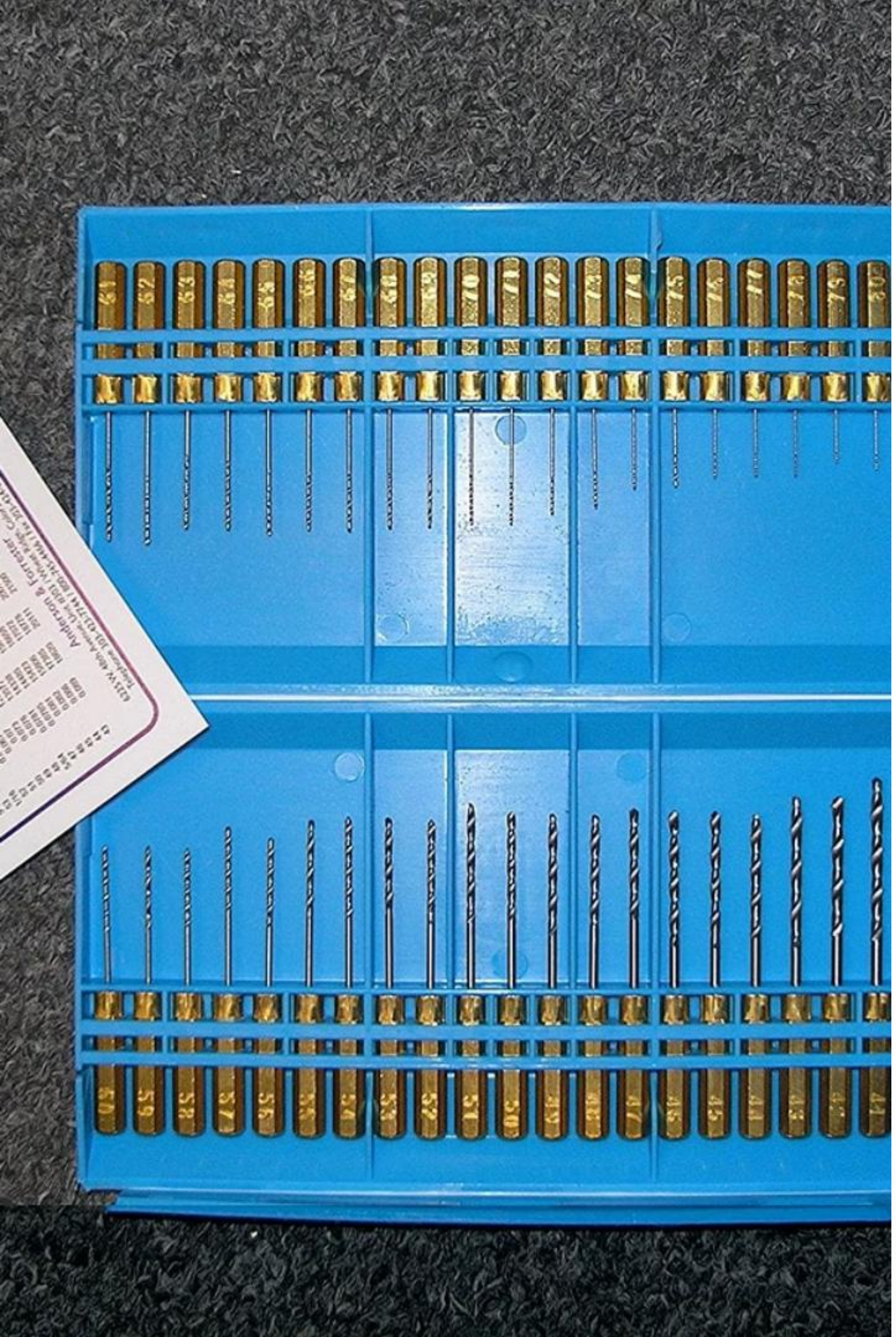
Nominal pressure at the burner for Natural Gas is 3.5" of water column. (Typical machine supply 5" - 7").

Pipe length must include additional length for all fittings. Add approximately 5 feet of pipe per fitting.

Natural Gas Example: A machine with a burner that requires 440,000 BTU would need a 1 - 1/4" pipe for a 20' long run.

LIQUID PROPANE

PIPE LENGTH (feet)	1/2"	3/4"	1"	1 - 1/4"	1 - 1/2"	2"	2 - 2 1/2"	3"	4"
10	275	567	1071	2205	3307	6221	10140	17990	35710
20	189	393	732	1496	2299	4331	7046	12510	25520
30	152	315	590	1212	1858	3465	5695	10110	20620
40	129	267	504	1039	1559	2992	4778	8481	17300
50	114	237	448	913	1417	2646	4343	7708	15730
60	103	217	409	834	1275	2394	3908	6936	14150
70	89	185	346	724	1086	2047	3329	5908	12050
80	78	162	307	630	976	1811	2991	5309	10830



Orifice Sizing

Gas Type

Different gases require different orifice sizes due to variations in specific gravity and calorific value

Calculate Input

Determine the required BTU input for the appliance

Pressure Consideration

Account for the gas pressure at the orifice

Select Orifice

Choose the correct orifice size based on calculations

Orifice sizing is critical when converting appliances between natural gas and propane. Due to propane's higher calorific value, propane orifices are typically smaller than those for natural gas to deliver the same heat output.

Propane Tank Filling Safety

80% Fill Rule

Propane tanks should never be filled beyond 80% of their capacity to allow for thermal expansion of the liquid.

Weight Method

One method to ensure proper filling is to weigh the tank and stop filling when the correct weight is reached.

Fixed Liquid Level Gauge

Many tanks have a fixed liquid level gauge (bleeder valve) that indicates when the 80% level is reached.

Float Gauge

Some tanks use a float gauge that directly indicates the percentage of fill in the tank.

Propane Cylinder Storage Requirements

Outdoor Storage

- Store cylinders outdoors in a well-ventilated area
- Keep away from building openings, air intakes, and ignition sources
- Maintain minimum clearance distances from buildings
- Protect from vehicle traffic with barriers if necessary

Position

- Store cylinders upright with relief valve in direct communication with the vapor space
- Secure cylinders to prevent tipping
- Keep valve protection caps in place when not in use

Environmental Factors

- Protect from direct sunlight and excessive heat
- Keep away from corrosive environments
- Ensure area is free from combustible materials

Natural Gas Distribution System

Transmission Pipelines

High-pressure pipelines transport natural gas from production facilities to distribution centers, typically operating at pressures between 200 and 1,500 psig.

City Gate Stations

These facilities reduce the pressure from transmission levels to distribution levels and add odorant to the gas.

Distribution Mains

Medium-pressure pipelines (typically 1-60 psig) that carry gas throughout service areas.

Service Lines

Low-pressure lines (typically 0.25-2 psig) that connect distribution mains to individual customers.

Meter and Regulator

Equipment at the customer location that measures gas usage and reduces pressure to appliance level (typically 0.25 psig or 7 inches water column).

Propane Distribution System

Production Facilities

Propane is produced at natural gas processing plants and petroleum refineries.

Storage Terminals

Large pressurized tanks store propane in liquid form at distribution hubs.

Transport

Propane is transported via pipeline, rail, truck, or ship to bulk plants.

Bulk Plants

Regional facilities that store propane and fill delivery trucks.

Customer Delivery

Propane is delivered to customer locations and stored in on-site tanks or cylinders.

Red Seal Alignment

CSA Gas Trade Unit	Title	2014 Red Seal Block
3	Properties, Characteristics, and Safe Handling of Fuel Gases	A - Common Occupational Skills

This unit aligns with the following Red Seal tasks:

- [x] **Task 1**

  Performs safety-related functions

- [ ] **Task 2**

  Maintains and uses tools and equipment

- [ ] **Task 3**

  Plans and prepares for installation, service and maintenance

Chapter Summary

Common Fuel Gases

We explored natural gas and propane, their composition, and sources

Physical Properties

We examined specific gravity, expansion factors, boiling points, and calorific values

Combustion Data

We studied flammability limits, ignition temperatures, and flame characteristics

4

Safety Considerations

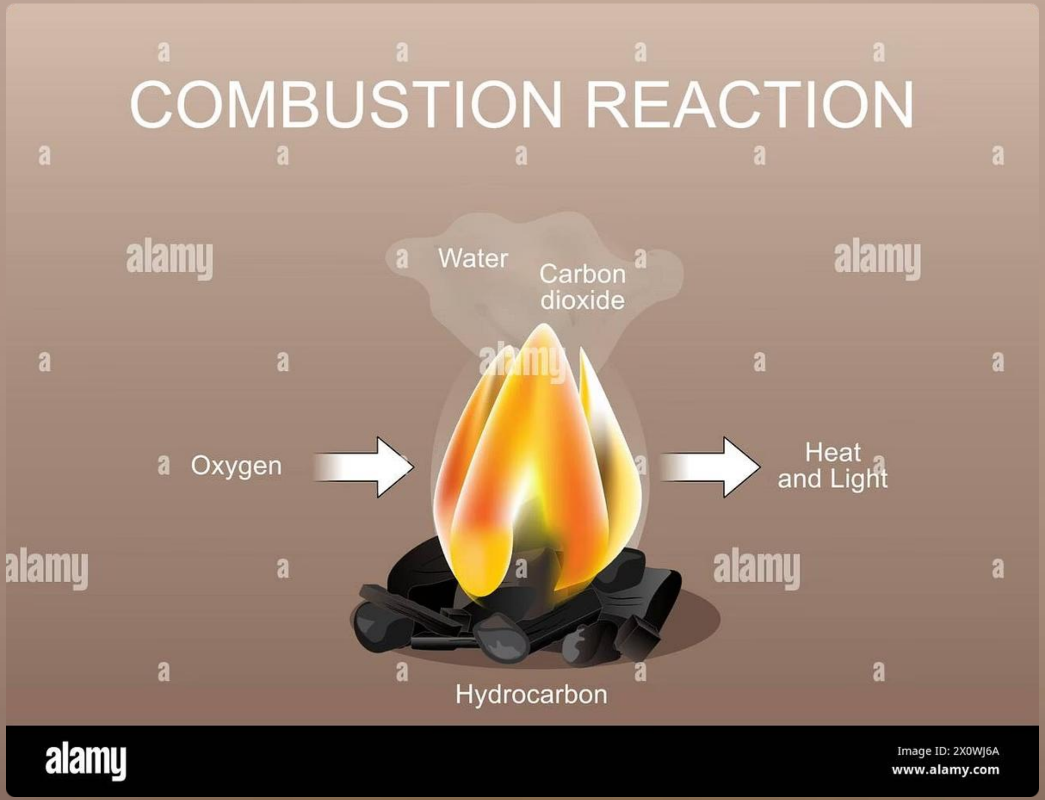
We covered odorization, leak detection, and safe handling practices

Understanding the properties and safe handling of fuel gases is essential for gas technicians/fitters to properly troubleshoot and adjust equipment. The next chapter will explain the principles of combustion in more detail.

CSA Unit 3

Chapter 2 Combustion

The gas technician/fitter must ensure safe and controlled combustion is occurring in an appliance's combustion zone. The technician's/fitter's understanding of the combustion process and the chemical reactions involved are the basis for much of the installation and service work they will perform in the gas industry.



Objectives

Explain the requirements of combustion

Understand the fundamental elements needed for combustion to occur

Describe differences between complete and incomplete combustion

Identify the chemical processes and outcomes of different combustion types

Describe air supply requirements

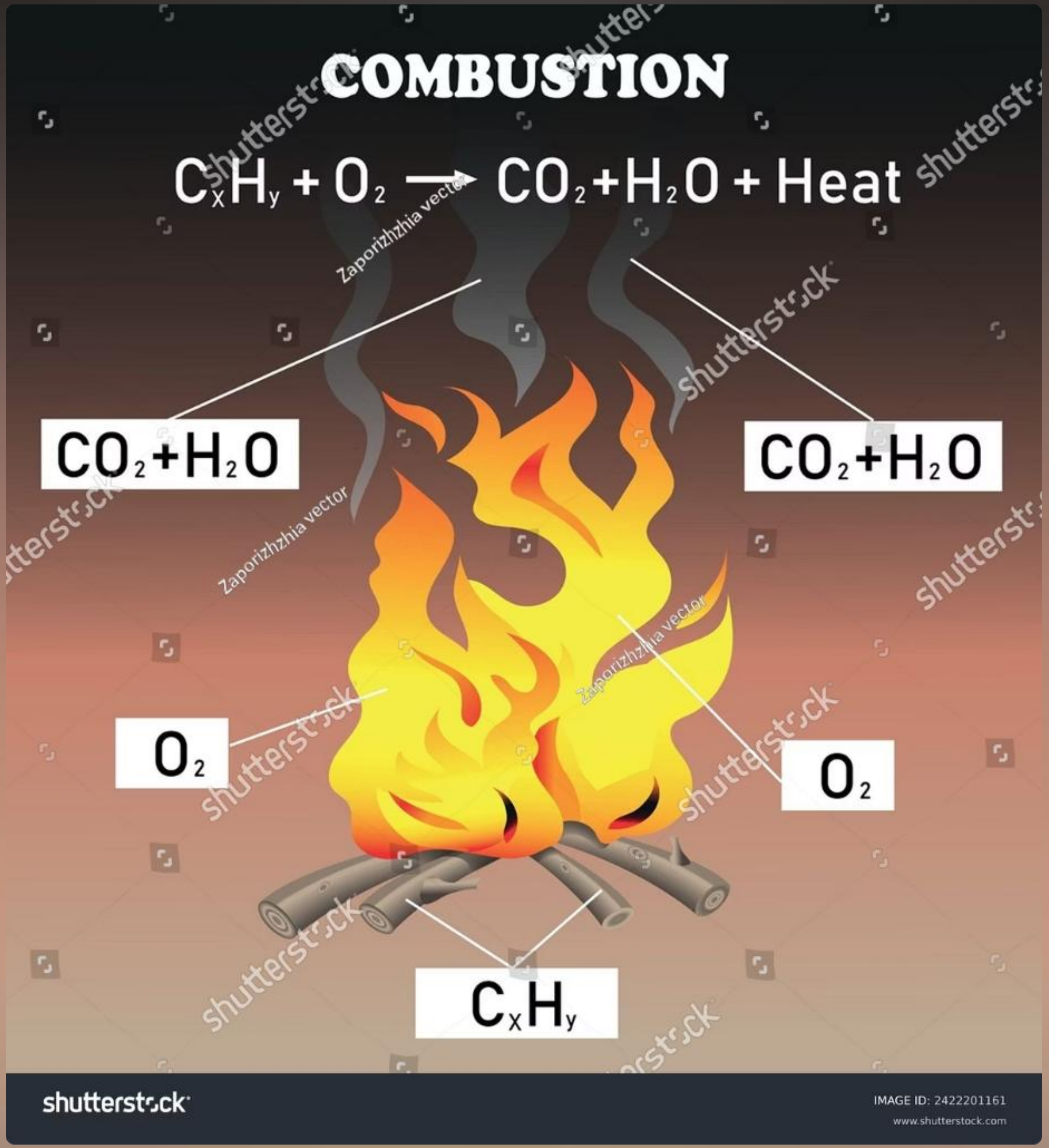
Understand the various air components needed for proper combustion

Describe causes of incomplete combustion

Recognize factors that can lead to dangerous combustion conditions

Describe characteristics and requirements of a stable flame

Identify proper flame appearance and conditions for safe operation



Key Terminology

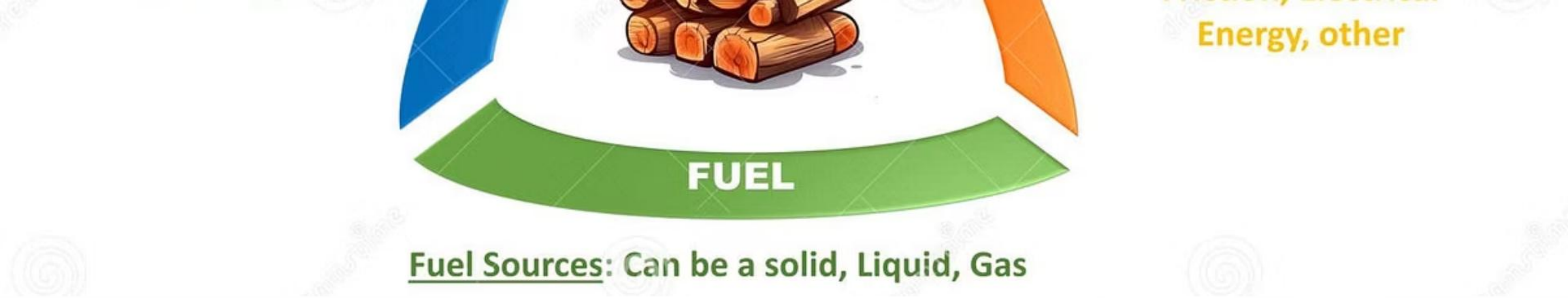
Term	Abbreviation (symbol)	Definition
Combustion		A chemical process in which the rapid oxidation of fuel results in the production of energy (heat)
Combustion air		The air for the satisfactory combustion of a gas
Complete combustion		All fuel is completely burned, and no harmful products of incomplete combustion are produced
Dilution air		The ambient air that is admitted to a venting system at the draft control device of the appliance

More Terminology

Term	Abbreviation (symbol)	Definition
Excess air		The air supplied to the combustion zone in excess of the required air for perfect combustion
Ventilation air		Air that is admitted to a space containing an appliance to replace air exhausted through a ventilation opening or by means of exfiltration
Flue gas condensation		Process that involves the cooling of flue gas below its water dew point and the recovery of heat released from the resulting condensation as low temperature heat
Incomplete combustion		The lack of oxygen to burn the fuel gas completely

Final Terminology

Term	Abbreviation (symbol)	Definition
Parts per million	ppm	Measurement of one part per 1,000,000 (10^6)
Perfect or stoichiometric combustion		Theoretical (or mathematically exact) volume of air that you must mix with fuel gas to achieve perfect combustion
Pounds per square inch absolute	psia	Pressure resulting from a force of one pound-force applied to an area of one square inch; pressure is relative to a vacuum rather than the ambient atmospheric pressure



Requirements of Combustion

Combustion is a chemical process in which the rapid oxidation of fuel results in the production of energy (heat). To start and sustain combustion, you must have three ingredients mixed together in the correct proportions:

Fuel

Usually natural gas or liquid petroleum gases

Oxygen

Obtained from the air surrounding a burner

Heat

Enough to bring the fuel to ignition point

Uninhibited Chemical Chain Reaction

Allows the combustion process to continue

The Combustion Triangle

If any one of these elements is absent, combustion will not take place nor will it support itself after an element is removed. This three-way relationship is commonly referred to as the combustion triangle.

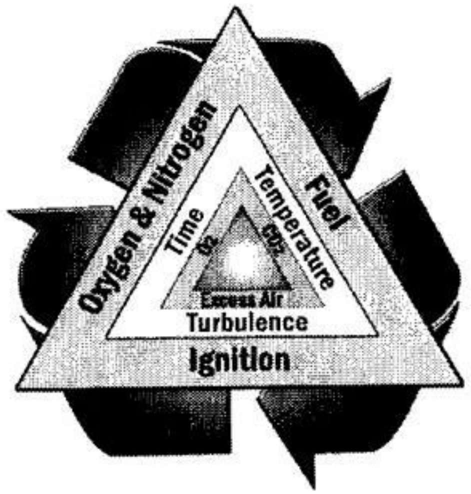


Figure 2-1 The combustion triangle and advanced combustion triangle

You can think of the combustion process as a living entity--it requires air to breathe, fuel as nourishment, and heat as an environment. Without one of the three, combustion ceases to exist.

The combustion triangle introduces the three basic elements required for combustion: air (O2 and N2), fuel (hydrocarbon), and ignition (heat). The advanced combustion triangle introduces additional elements that aid the technician/fitter in understanding and controlling combustion: time, temperature, turbulence, oxygen, carbon dioxide, and excess air.

Nitrogen in Combustion

Nitrogen introduced into the combustion system is an inert gas, in that it doesn't chemically react in the combustion process. Nitrogen does absorb heat, increase flue gas volume and, at high flame temperatures, has a thermal fixation for oxygen, binding to oxygen to form nitric oxide and nitrogen dioxide commonly referred to as NOx gasses. NOx gases are toxic, and concentrations of 15 ppm are immediately dangerous to life and health.

Fuel

Natural gas, propane, and butane are hydrocarbon fuels burned in a gaseous state.

Heat/ignition

Igniting the air gas mixture requires the supply of enough heat by a previously lit small flame such as a pilot, an ignition spark, or a hot surface igniter. Once you have provided this initial heat, the heat released from the combustion process sustains itself.

Oxygen

For the combustion process to consume oxygen, it must be readily available. Generally, the required oxygen supply comes from the air. Because air contains only 20% oxygen and 80% nitrogen, we must supply a much larger volume of air than the combustion process would require if the supply were pure oxygen.

Advanced Combustion Elements

Temperature

Temperature of combustion is important for efficiency and combustion control. The better the air fuel mixture, the more time the flame is given to burn, and the hotter the flame temperature. The increased flame temperature increases the radiant heat transfer to the heat exchanger.

Time

Time is an important variable for combustion control. Time relates to the air fuel mixture and how long the flame is given to burn. Time relates to temperature.

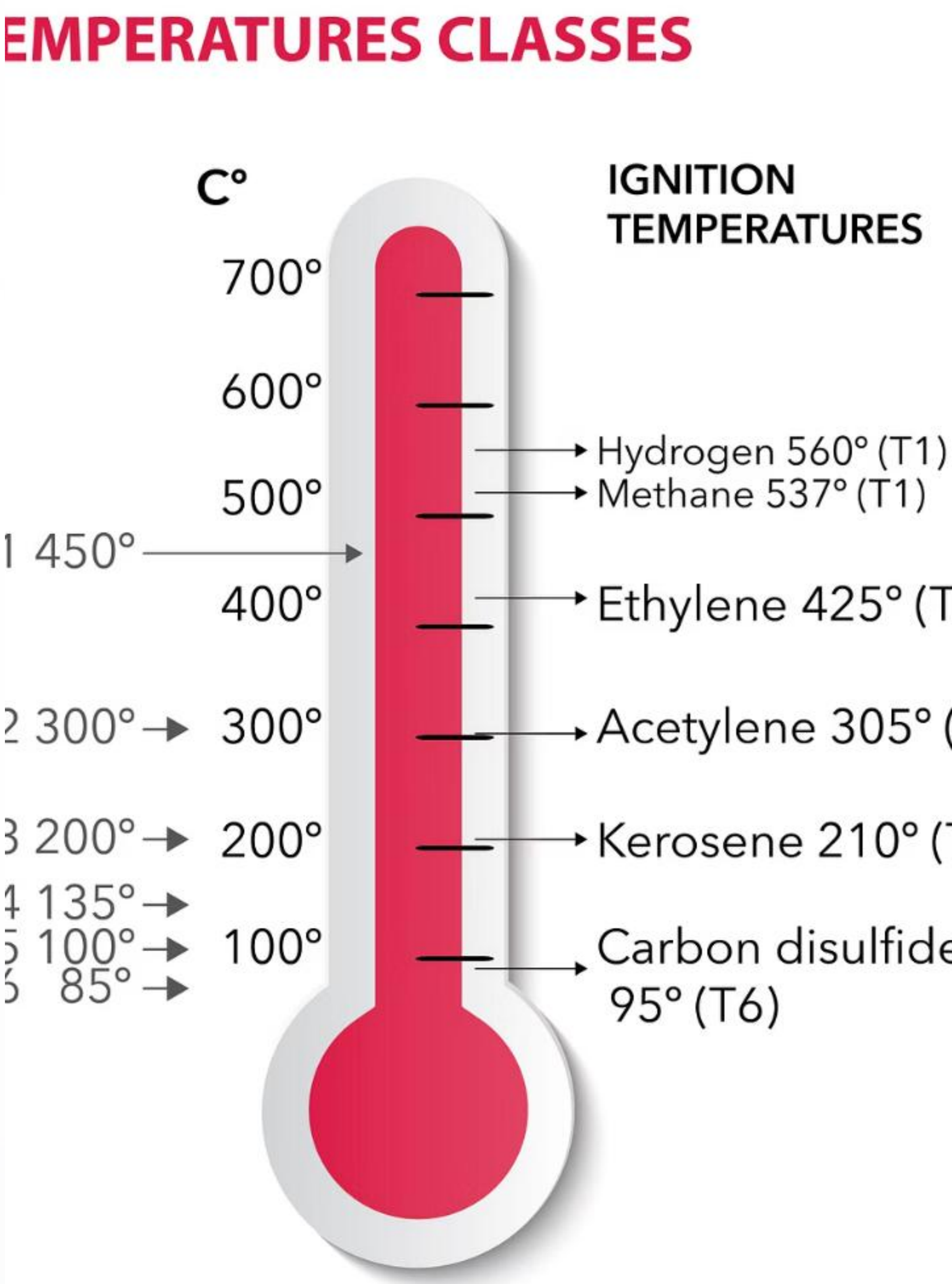
Turbulence

Turbulence relates to the air fuel mixture, flame temperature, and heat transfer. Time, temperature, and turbulence all relate to oxygen, carbon dioxide, and excess air, in that better mixing of air and fuel reduces the amount of excess air required for complete combustion. The decrease in excess air increases flame temperature and increases the percentage of carbon dioxide in the products of combustion. The decrease in excess air reduces the volume of oxygen remaining after combustion.

Ignition Temperatures

Gas	Chemical designation	Ignition temperature
Natural gas	CH_4	1,300°F (700°C)
Propane	C_3H_8	920°F (495°C)

Ignition temperatures vary according to the type of gas used, as shown in the table above. Each fuel has a specific temperature at which it will ignite and sustain combustion.



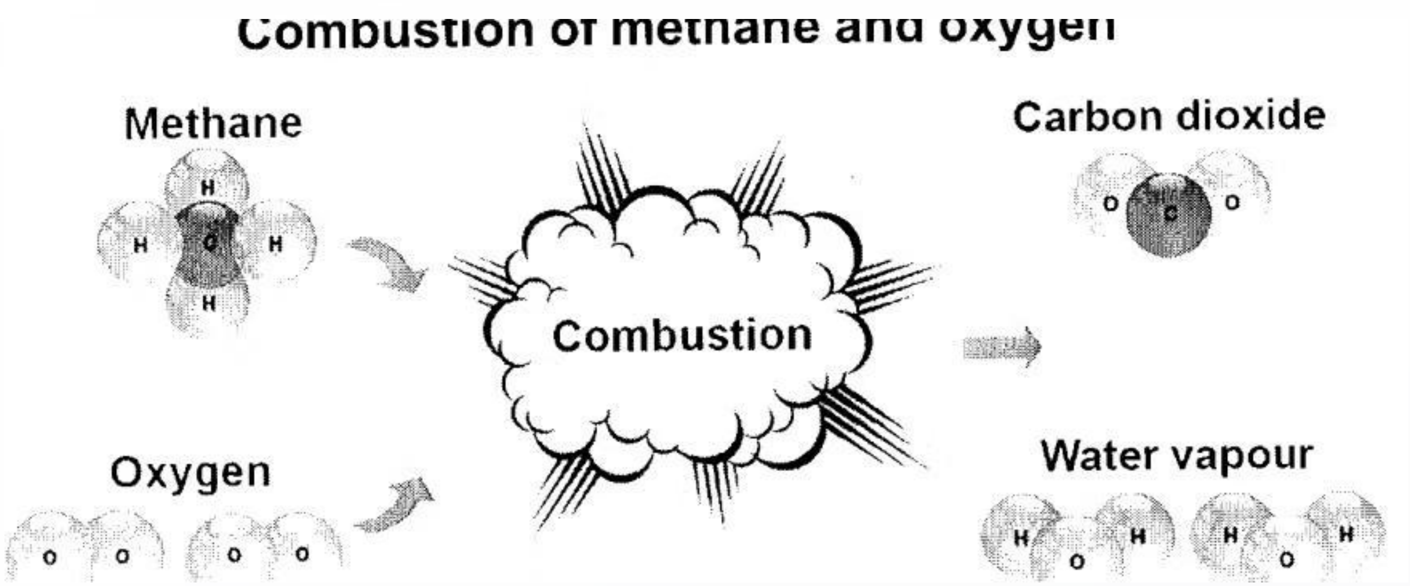
The Chemistry of Combustion

The chemistry of combustion is the reaction which takes place between fuel gas and oxygen when heated to ignition temperature. Mixing the elements of hydrocarbons with enough oxygen to support combustion leads to the formation of carbon dioxide and water vapor, and the release of heat as the products of combustion.

Natural Gas (Methane) Reaction

The chemical formula expressing the combustion reaction for natural gas and oxygen is:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat



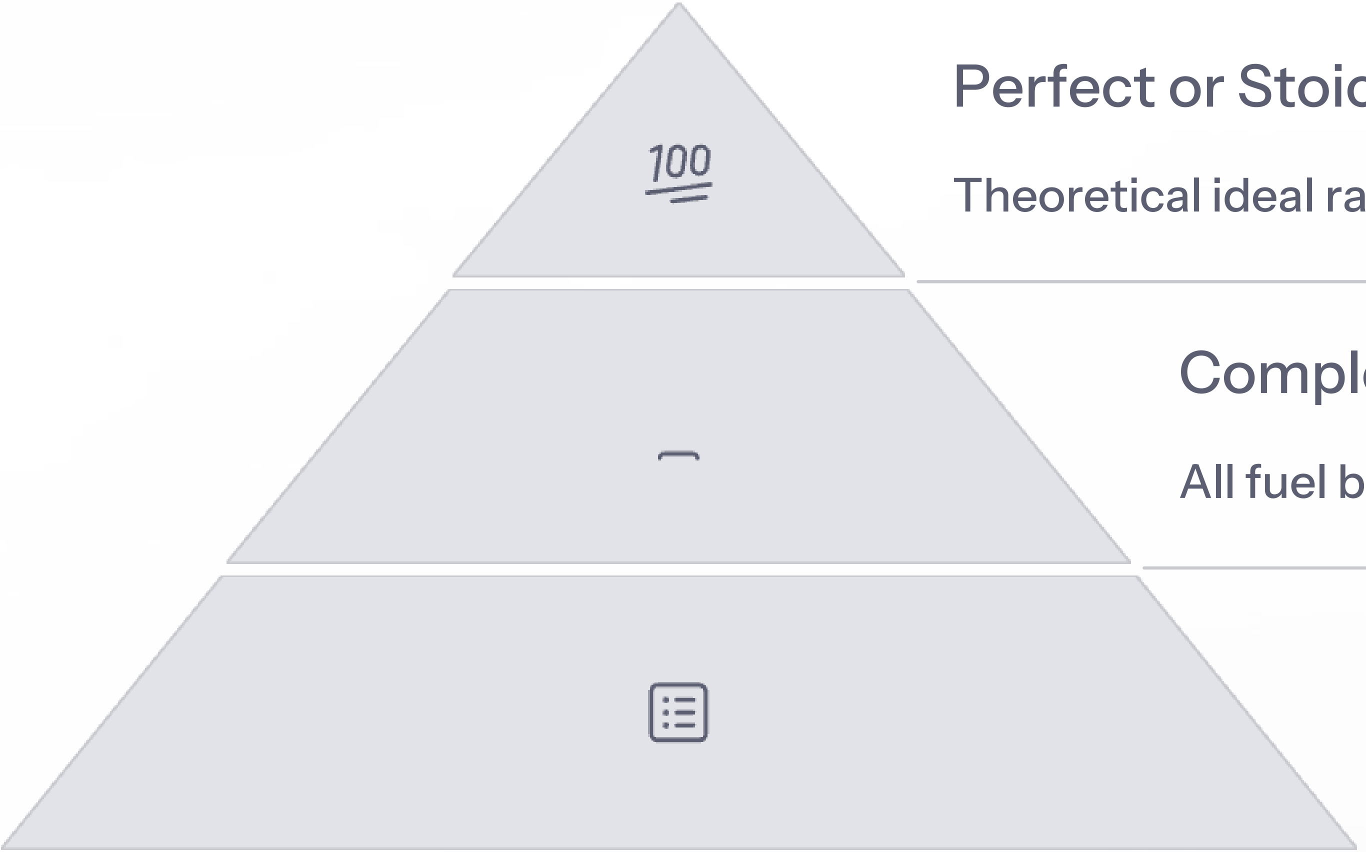
Propane Reaction

The chemical formula describing the combustion for propane and oxygen is:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ + heat

Types of Combustion

This section describes the following three types of combustion, each determined by the initial air supply:



Perfect or Stoichiometric Combustion

Theoretical ideal ratio

Complete Combustion

All fuel burned with excess air

Incomplete Combustion

Insufficient oxygen for full burning

Perfect or Stoichiometric Combustion

Perfect or stoichiometric combustion refers to the theoretical (or mathematically exact) volume of air that you must mix with fuel gas to achieve perfect combustion. This gas-air mixture is often called the ideal combustion ratio.

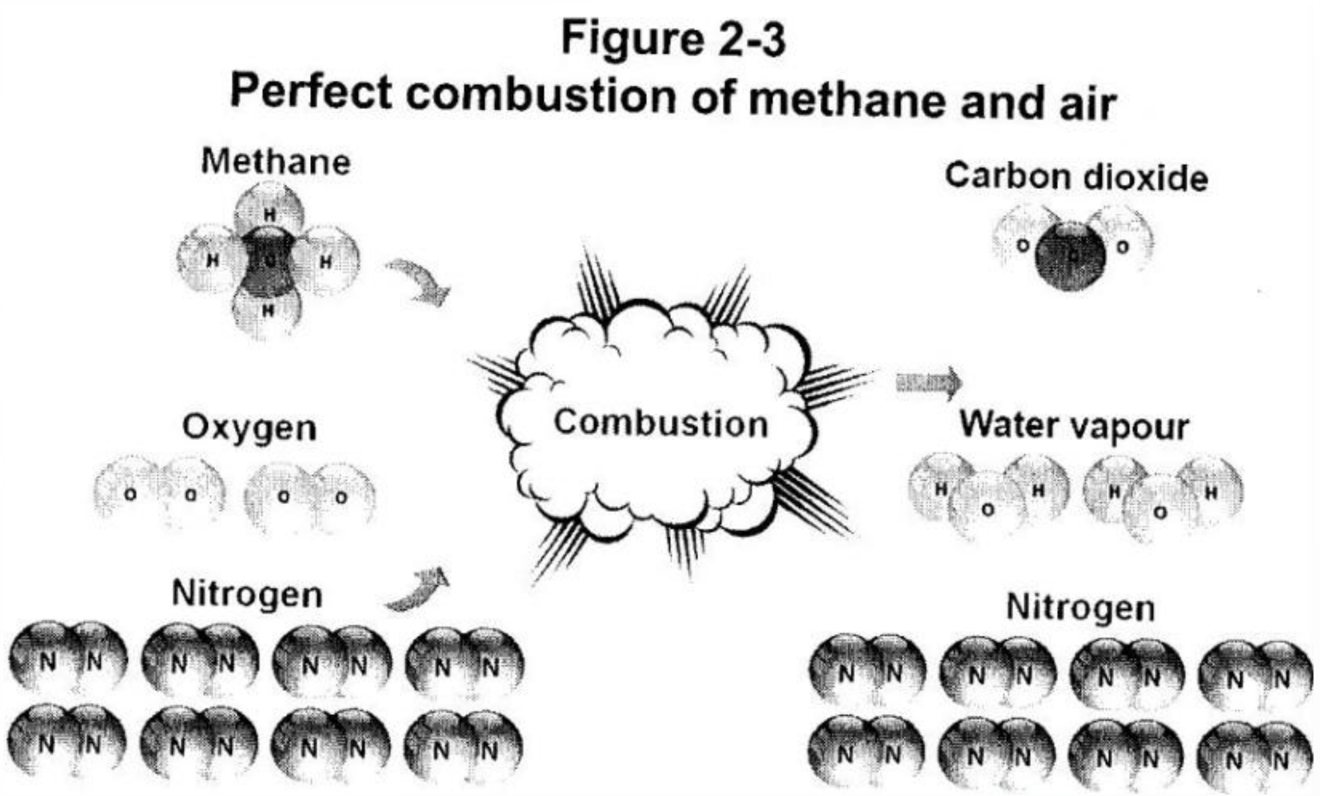
The formula for perfect combustion is used for theoretical calculations only. This is because most burners cannot practically mix exact gas and air volumes together to produce satisfactory combustion. In practice, some of the hydrogen and carbon produced will combine with oxygen, so incomplete combustion will occur.

Because air is 20% oxygen (O_2) and 80% nitrogen (N_2), nitrogen is included in the perfect combustion formula. In the following formula for perfect combustion, there are 8 parts of nitrogen to two parts of oxygen. Note that nitrogen is inert and doesn't chemically react in the combustion process, although at high flame temperatures it has a thermal fixation for oxygen.

Perfect Combustion Formula

Natural Gas (Methane)

$CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 8N_2 + heat$



Propane

$C_3H_8 + 5O_2 + 20N_2 \rightarrow 3CO_2 + 4H_2O + 20N_2 + heat$

These formulas represent the ideal theoretical combustion process where exactly the right amount of oxygen is present to completely burn the fuel.

Complete Combustion

Since perfect combustion is only possible in theory, you must adjust the equipment to ensure complete burning of all fuel and prevent the production of harmful products from incomplete combustion. This process is complete combustion.

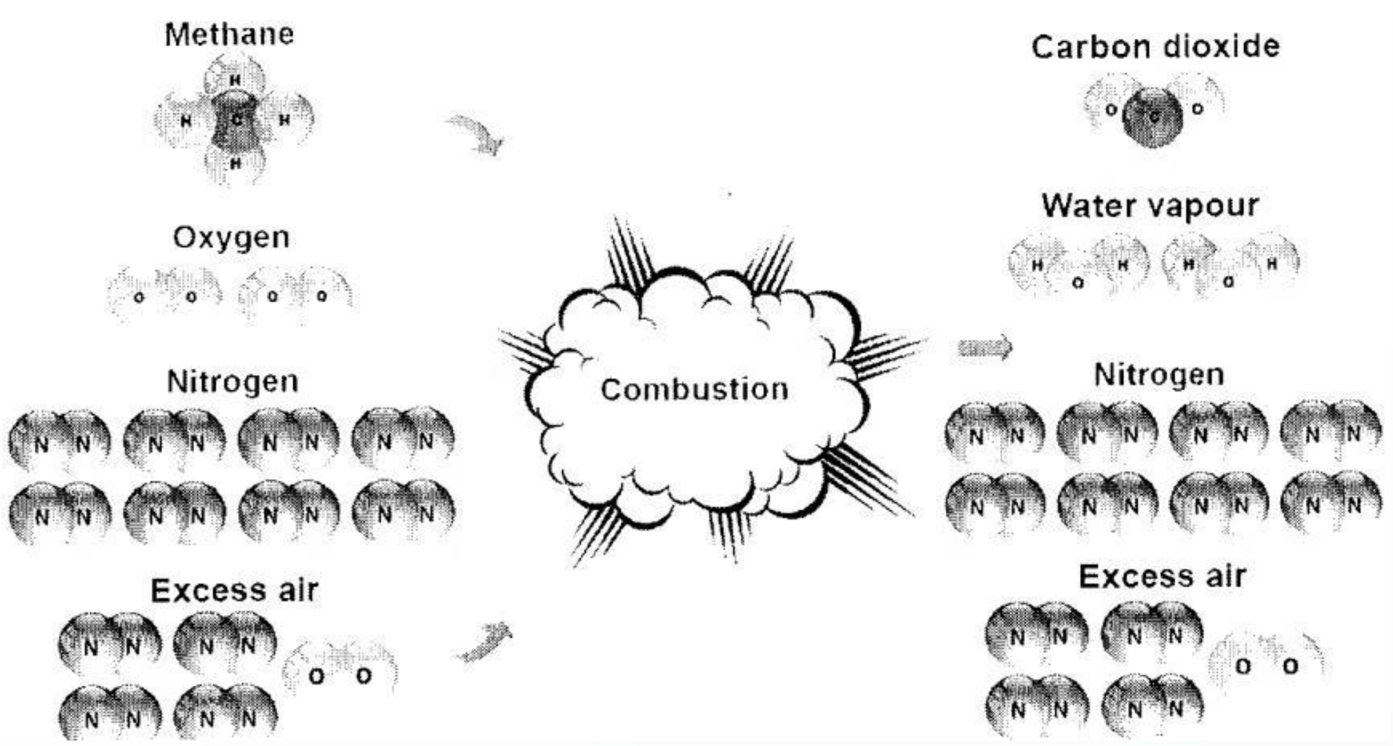
Normally, to achieve combustion, technicians/fitters supply more air to the combustion process than perfect combustion requires to ensure that all atoms of carbon and hydrogen united with enough atoms of oxygen to produce complete combustion.

Natural Gas Formula

$CH_4 + 2O_2 + 8N_2$ + excess air → $CO_2 + 2H_2O + 8N_2$ + excess air + heat

Propane Formula

$C_3H_8 + 5O_2 + 20N_2$ + excess air → $3CO_2 + 4H_2O + 20N_2$ + excess air + heat



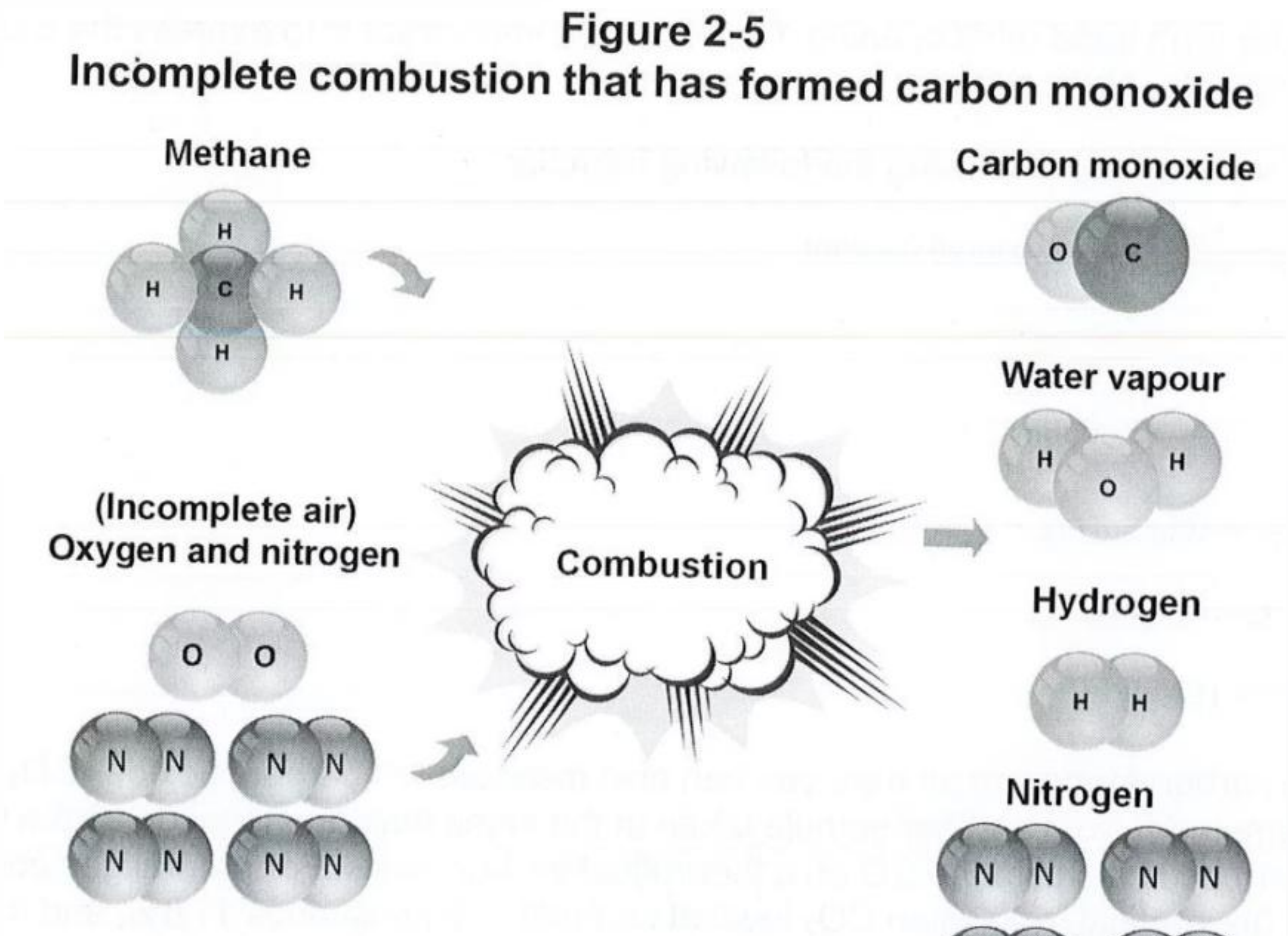
Incomplete Combustion

Where there is not enough oxygen to burn the fuel gas completely, some of the fuel will not unite with its oxygen counterpart and will leave unburned fuel in the flue gas. The unburned fuel will contain carbon, hydrogen, carbon monoxide, and complex chains of alcohols called aldehydes.

The flue gas products of incomplete combustion (particularly carbon monoxide and hydrogen) are often grouped together as combustibles. Carbon monoxide and aldehydes in any quantity are toxic and life threatening.

Natural Gas Formula

$CH_4 + 1O_2 + 4N_2 \rightarrow CO + H_2O + H + 4N_2 + heat$



Propane Formula

$C_3H_8 + 4O_2 + 16N_2 \rightarrow CO + H_2O + H + 16N_2 + heat$

These formulas show how insufficient oxygen leads to incomplete combustion and the formation of carbon monoxide instead of carbon dioxide.

Products of Incomplete Combustion

Carbon Monoxide (CO)

Carbon monoxide is one of the most harmful products of incomplete combustion. It is toxic (i.e., it can cause death if enough is inhaled). Since it has no odour, taste, or smell, it is hard to detect without proper equipment. In higher concentrations, it is combustible.

Aldehydes

Aldehydes are a group of transparent, colourless gases with a suffocating smell, produced by the partial oxidation of fuel gas. Because of this, they are easily detected. They are toxic and irritating to the eyes, throat, and nose.

Other factors besides insufficient air can cause incomplete combustion. The Causes of Incomplete Combustion section describes these in more detail.

Measuring Carbon Monoxide

Measured carbon monoxide levels can vary greatly depending on where they are taken. For example, measurements taken upstream of the draft hood diverter on a water heater will render higher CO levels than downstream of the draft hood diverter due to dilution air entering the draft hood relief opening. One way to compensate is to express the CO measurement on an air-free basis.

CO Air Free Calculation

You can calculate CO air free using the following formula:

CO air free = 20.9 ÷ (20.9 - O2 measured) × measured CO ppm

Example:

CO air free = 20.9 ÷ (20.9 - 7.0) × 100ppm CO

CO air free = 20.9 ÷ 13.9 × 100ppm

CO air free = 1.50 × 100ppm CO

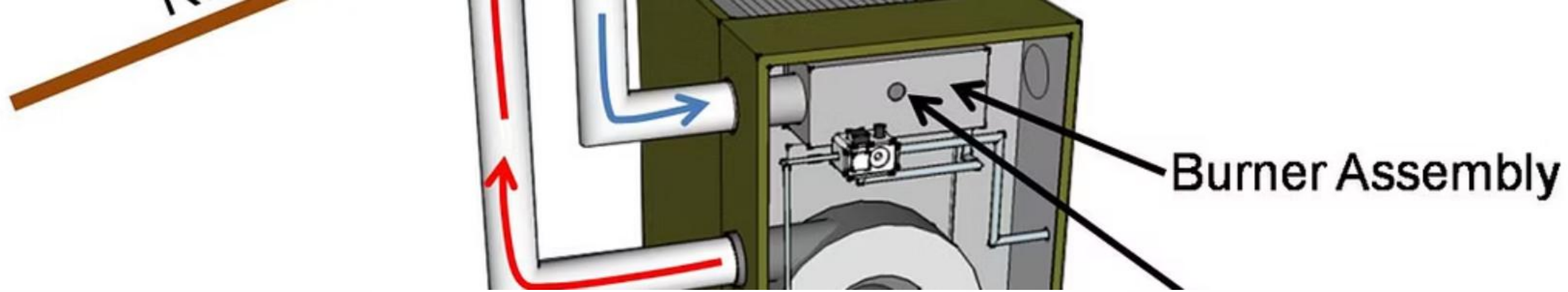
CO air free ppm = 150

Alternative Calculation Method

To calculate carbon monoxide air free, you can also measure the carbon dioxide (CO_2) level from the same sample and calculate the CO on a theoretical air-free basis. For natural gas combustion, the CO_2 level at complete combustion is 11.8%, and for propane, 13.8%.

The formula is:

CO (air-free) = CO (measured) × CO2 (ultimate) ÷ CO2 (measured)



Air Supply Requirements

The efficient and safe operation of gas-fired appliances relies on an adequate supply of air. For present purposes, we divide our air supply into three main categories:

Combustion Air (Theoretical)

The air required for the satisfactory combustion of a gas

Excess Air

Additional air to ensure complete combustion

Dilution Air

Air that cools hot vent gases and controls draft

Combustion Air Types

Combustion air is the air required for the satisfactory combustion of a gas. Normally, combustion air includes excess air, but here, combustion air will refer to the theoretical air discussed earlier in perfect combustion.

You can further classify combustion air into two:

Primary Air

Primary air refers to the combustion air that is mixed with fuel gas before ignition. The amount of primary air is normally considered to be one-third of the theoretical amount of air used for combustion.

Secondary Air

The secondary air required to complete the combustion of the gas is mixed with the fuel at the point of combustion. Secondary air is supplied from around the flames and is generally considered to be two-thirds of the theoretical air considered for perfect combustion.

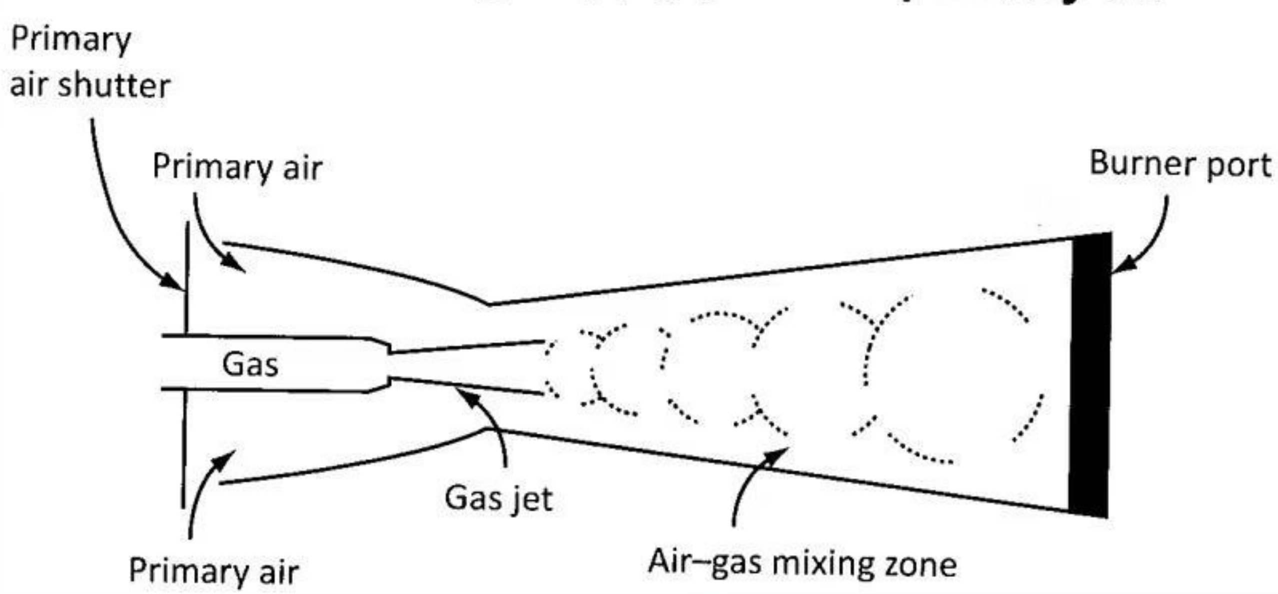


Figure 2-6
Burner showing supply point of primary air

Secondary Air Supply

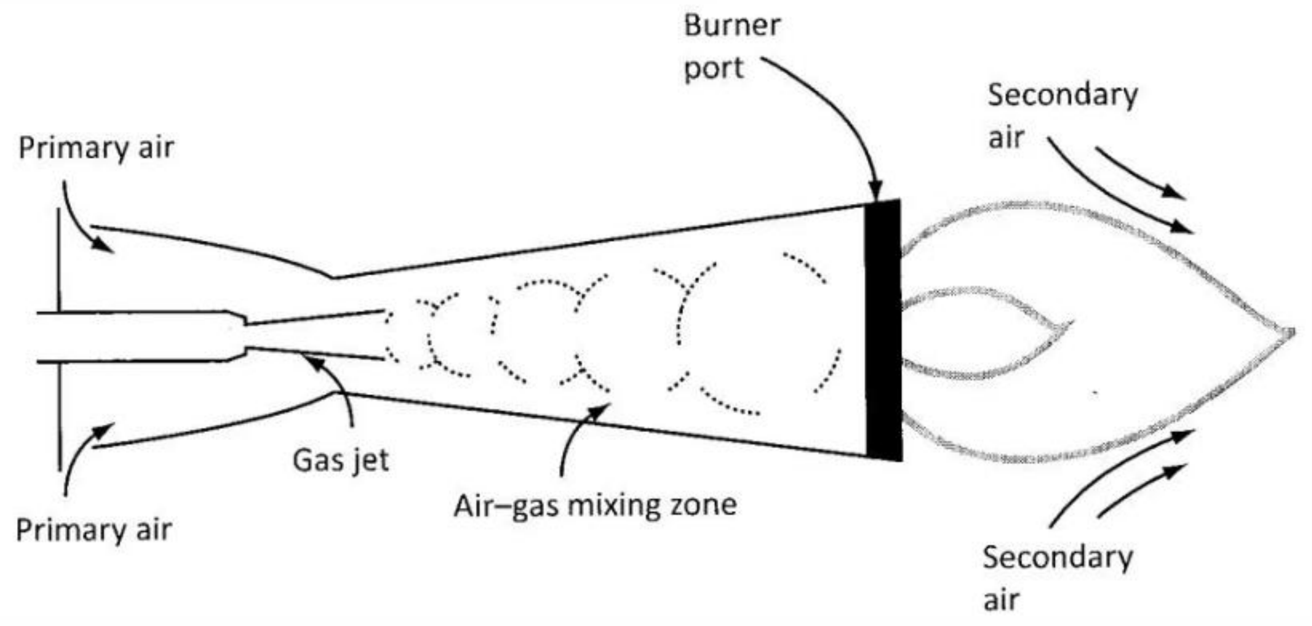


Figure 2-7 Supply to burner of primary and secondary air around the flame

Secondary Air Function

Secondary air completes the combustion process by providing additional oxygen at the flame itself. This air is not pre-mixed with the gas but instead surrounds the flame and mixes during combustion.

The proper balance of primary and secondary air is crucial for efficient and complete combustion. Too little secondary air can result in incomplete combustion and the formation of carbon monoxide.

Excess Air

Excess air is the air you supply to the combustion zone in excess of the required air for perfect combustion to ensure there is sufficient oxygen for complete combustion to occur. Because the excess air is over and above what is theoretically needed in the combustion process, it absorbs heat, which it carries off through the venting system. This, in turn, reduces the appliance's efficiency. So, you must keep excess air to a minimum.

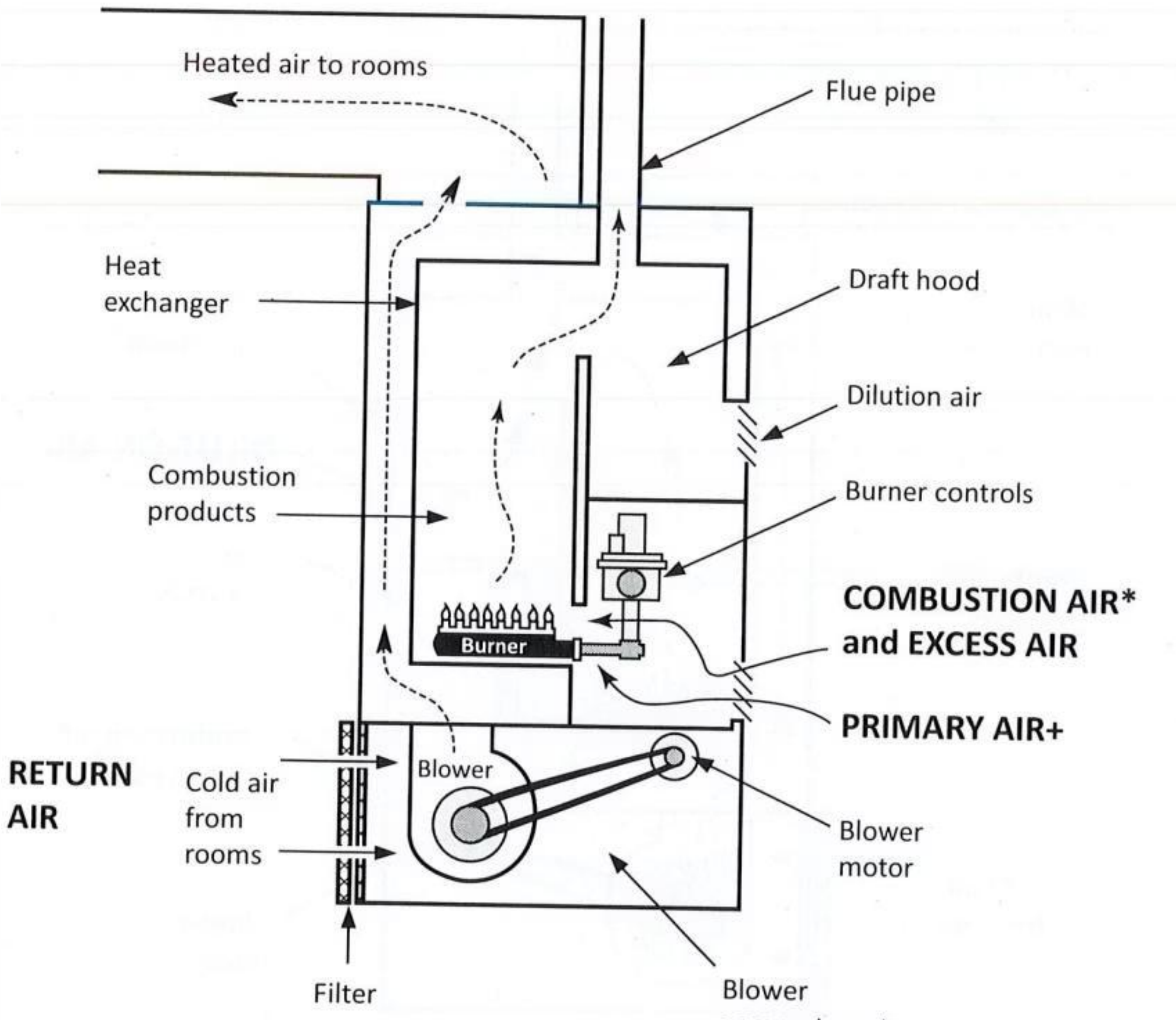


Figure 2-8
Cutaway of a furnace showing combustion and excess air

Figure 2-8 shows where combustion and excess air are brought into a furnace.

* Combustion air = primary air + secondary air

Dilution Air

Dilution air is the ambient air that is admitted to a venting system at the draft control device of the appliance. Use it for two purposes:

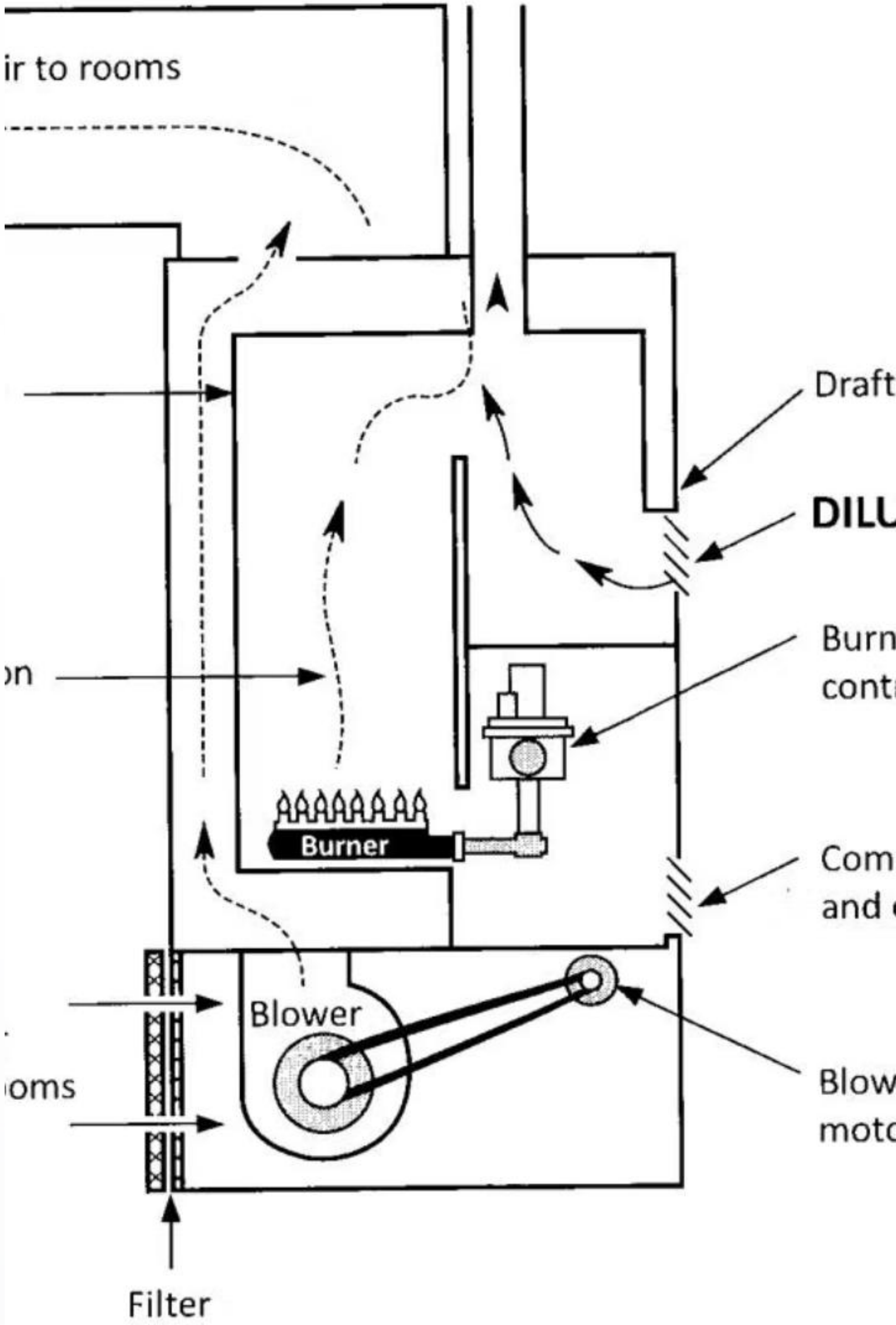
Cool the hot vent gases

Reduces the temperature of combustion products in the venting system

Provide a source of air to the draft control device

Allows the device to control the draft influence on the combustion chamber

The lack of a draft control device in the equipment means no dilution air is required.



Calculating Air Supply Volumes

For the purpose of calculating volumes of required air, air supply has the following categories:

Combustion air supply

The theoretical air needed for perfect combustion

Excess air supply

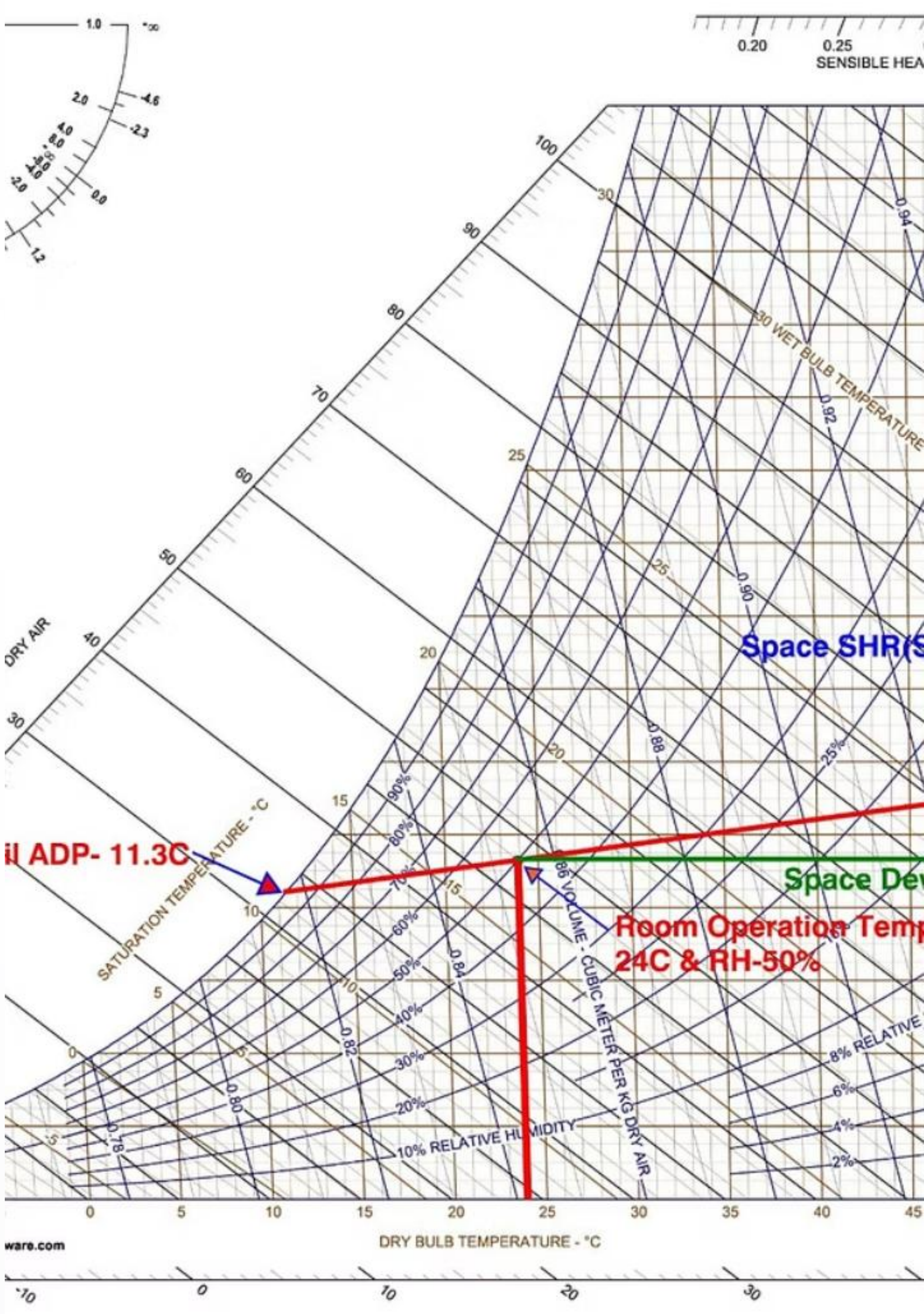
Additional air to ensure complete combustion

Dilution air supply

Air for cooling and draft control

Total air supply

The sum of all air requirements



Combustion Air Supply Volume

The natural gas industry has always used a 10:1 ratio for the air-gas mixture required to achieve perfect combustion. This, of course, refers only to natural gas and air. In terms of volume, one cubic foot (1 ft^3) of natural gas combines with 10 cubic feet (10 ft^3) of air.

1 ft^3 CH4 + 10 ft^3 air = perfect combustion

As a gas technician/fitter, you will work with many types of fuel gases, and they all have something in common when it comes to perfect combustion. For each 1,000 Btu of heat the combustion process produces, you will need 10 ft^3 of air for perfect combustion. See the following formula:

1,000 Btu of input + 10 ft^3 air = perfect combustion

You can still apply the ratio of 10:1, but it means that you need 10 ft^3 of air for each 1,000 Btu of input. Thus, you could express a new ratio, applicable to all fuel gases:

Each (1,000 Btu of input) × 10 ft^3 = perfect combustion

Combustion Air Calculation Examples

Example 1 - Natural Gas

Calculate the volume of combustion air required for an appliance with an 80,000 Btu/h input, fired on natural gas.

80,000 Btu/h × 10 ÷ 1,000 = 800 ft^3/h combustion air

Example 2 - Propane

Calculate the volume of combustion air required for an appliance with a 25,000 Btu/h input, fired on propane.

25,000 Btu/h × 10 ÷ 1,000 = 250 ft^3/h combustion air

1,000 Btu of input requires 10 ft^3 of combustion air supply, whatever the type of fuel gas used.

Excess Air Supply Volume

The excess air that you supply to a burner ensures the combination of all fuel with oxygen to produce complete combustion. A lack of excess air may cause varying degrees of incomplete combustion, while too much excess air can cool the flame and cause incomplete combustion. Too much excess air will increase the volume of gases in the heat exchanger and may cause spillage of flue gases. Too much excess air will carry off heat, reducing the efficiency of the appliance.

Modern fan-assisted burners and power burners can operate efficiently, often with as little as 20-30% excess air. For atmospheric burners, complete combustion with a volume of excess air equal to 50% of the combustion air volume is usually acceptable. A relationship between Btu of input and the volume of excess air required can be as follows:

1,000 Btu of input requires 5 ft^3 of excess air supply.

Dilution Air Supply Volume

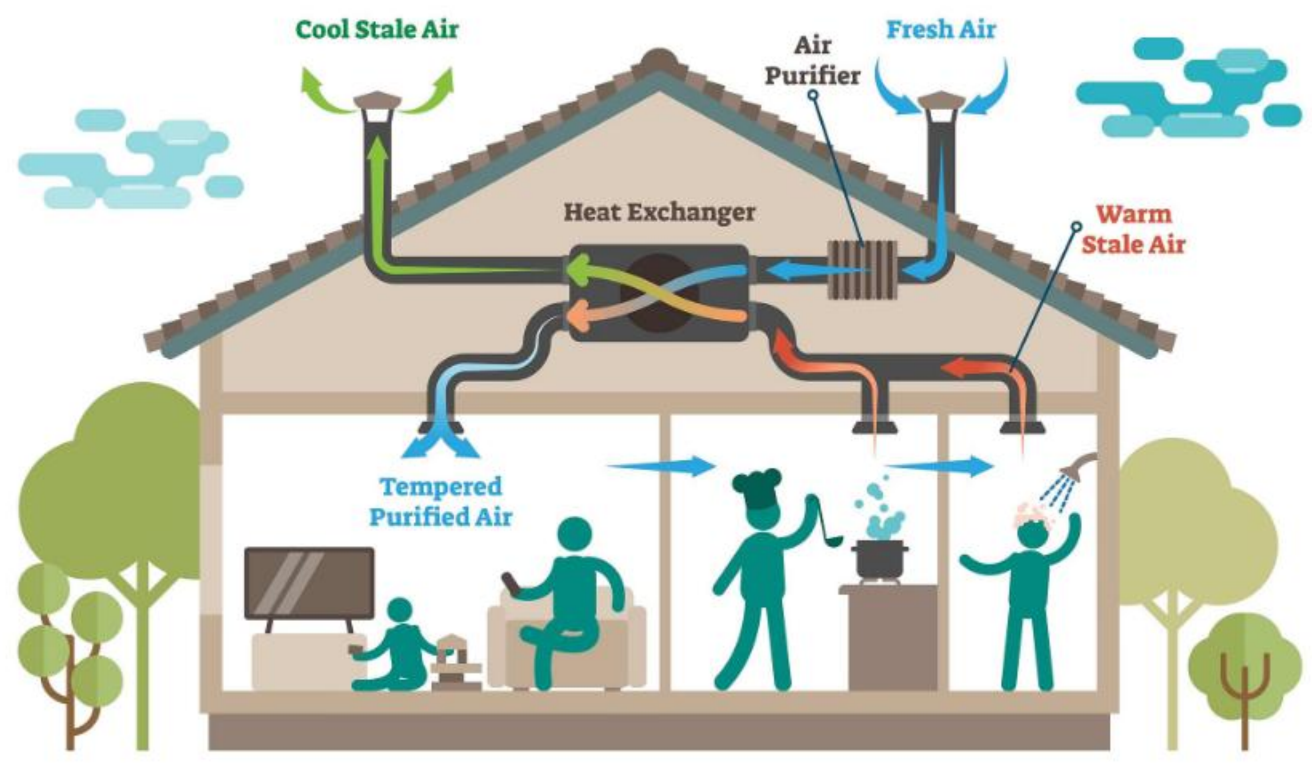
If an appliance comes with a draft control device, a volume of air must enter the venting system in order to cool and control the stack action. The required volume of dilution air being equal to the total of the combustion and excess air supplied to the burner is usually acceptable. The relationship between Btu of input and the volume of dilution air required is as follows:

1,000 Btu of input requires 15 ft^3 of dilution air supply.

Total Air Supply Volume

Use the term total air to describe the volume of air required to allow the safe and efficient operation of the appliance. It is a total of combustion, excess, and dilution air requirements. The relationship between Btu of input and the volume of total air required is as follows:

1,000 Btu of input requires 30 ft^3 of total air supply.

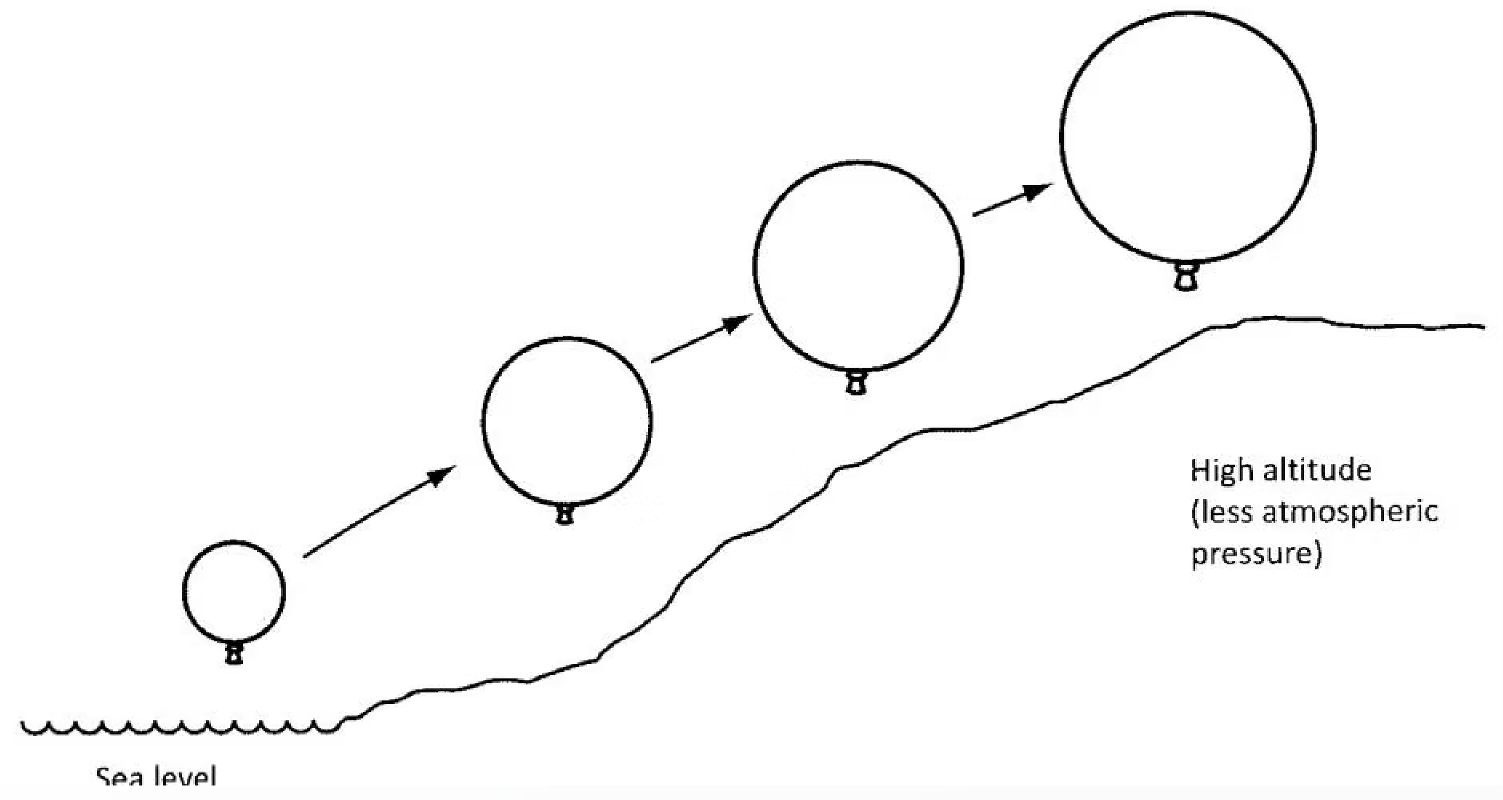


High Altitude Installations

Certain areas in Canada (e.g., regions in B.C. and Alberta) are located at high altitude. It is important that you understand the effect of reduced atmospheric pressure on combustion performance.

The barometric pressure at sea level is 14.73 psia. If you visualize a balloon filled with one standard ft^3 of natural gas at sea level 14.73 psia, the balloon expands in volume to equalize against the atmospheric pressure.

For every 2,000 ft rise in elevation, the barometric pressure reduces by approximately 1 psia. For example, as the altitude increases, the pressure exerted on the sides of the balloon reduces, and the lower the pressure, the more the balloon volume expands. At a 2,000 ft rise, the volume of natural gas would expand to approximately 1.072 ft^3 and become less dense. You can calculate the amount of expansion using Boyle's Law, which states "the volume of dry gas varies inversely to the absolute pressure, providing the temperature remains constant" or $p_1V_1 = p_2V_2$.



Effects of High Altitude

This reduction in gas density at high altitudes changes the gas flow into the orifice. Because the gas is less dense, it flows more easily through a burner orifice, increasing the gas flow to the appliance and putting the input-to-oxygen ratio out of balance.

Air Supply Summary

To determine the necessary volume of air supply, it is important that you identify the input of the appliances.

For each 1,000 Btu or 1 MBH of appliance input, the ratio of air is as follows:

- 1,000 Btu (1 MBH) of fuel × 10 = ft^3 combustion air
- 1,000 Btu (1 MBH) of fuel × 5 = ft^3 excess air
- 1,000 Btu (1 MBH) of fuel × 15 = ft^3 dilution air
- 1,000 Btu (1 MBH) of fuel × 30 = ft^3 total air

Causes of Incomplete Combustion

It is important to know that incomplete combustion occurs from causes other than insufficient air. For example, the combustion process must maintain a minimum temperature. If at anytime the flame is quenched below that temperature, then you may have incomplete combustion that produces toxic products.

Cause	Description
Flame temperature	The combustion process must maintain a temperature of approximately 1,300°F (649°C) for natural gas or 920°F (495°C) for propane. If at any time the flame is quenched below that temperature, you may have incomplete combustion and toxic products. Conditions that cause the temperature to drop below the ignition point may have this effect. These conditions include impingement on the cold metal surface of a heat exchanger or excessive cold air that chills the flame front.

More Causes of Incomplete Combustion

Cause	Description
Cracked heat exchanger	A heat exchanger is the component of a gas appliance that takes the heat from the hot flue gases and transfers it to the supply air that helps heat the building. On occasion, this component will develop a crack that allows the supply air to come into contact with the hot flue gases. This can cause excessive air movement in the combustion chamber and adversely affect the flame, causing incomplete combustion. If the flame characteristics change as soon as the supply air blower comes on, or if there is a change in CO_2 or O_2 levels in the flue gases when the blower starts, you may have a heat exchanger problem. On an induced draft appliance, a crack will result in less air for the combustion process and increased CO.

Blocked Venting Issues

Cause	Description
Blocked venting Natural draft appliance	If the venting on a gas appliance becomes blocked, the flue gases will not be able to reach the outdoors and will spill out of the draft hood and remain in the room. If the products of combustion are not leaving the room, then combustion air is not entering. In time, this lack of combustion air will cause incomplete combustion and a carbon monoxide condition. You can check spillage at the draft hood with a smoke stick to see if there is positive or negative pressure.
Induced draft appliance	If an appliance has a fan-assisted or induced-draft combustion chamber, it has sensing devices that will shut down the burner if the venting becomes blocked.

Negative Air Pressure

Cause	Description
Negative air pressure	Many venting systems rely on natural draft to move the products of combustion outdoors. Room pressure can affect this draft. If excessive air exhausted from the building produces a negative pressure in the room, the pressure will affect the combustion process and could cause incomplete combustion.

Effects of Negative Pressure

Negative pressure in a room can:

- Pull products of combustion back into the living space
- Disrupt the proper air-fuel mixture
- Cause flame rollout or lifting
- Lead to dangerous carbon monoxide production

Flue Gas Condensation

Flue gas condensation is a process that involves the cooling of flue gas below its water dew point and the recovery of heat released from the resulting condensation as low temperature heat.

When fuel is burned and the hot gases produced are exhausting through a heat exchanger, much of the heat is transferred to the medium passing through the heat exchanger, thus raising the temperature of the medium. One of the hot gases produced in the combustion process is water vapour (steam), which arises from burning the hydrogen content of the fuel. A condensing appliance extracts additional heat from the flue gases by condensing this water vapour to liquid water, thus recovering its latent heat. A typical increase of efficiency in the appliance can be as much as 10-20% of gain over a non-condensing appliance.

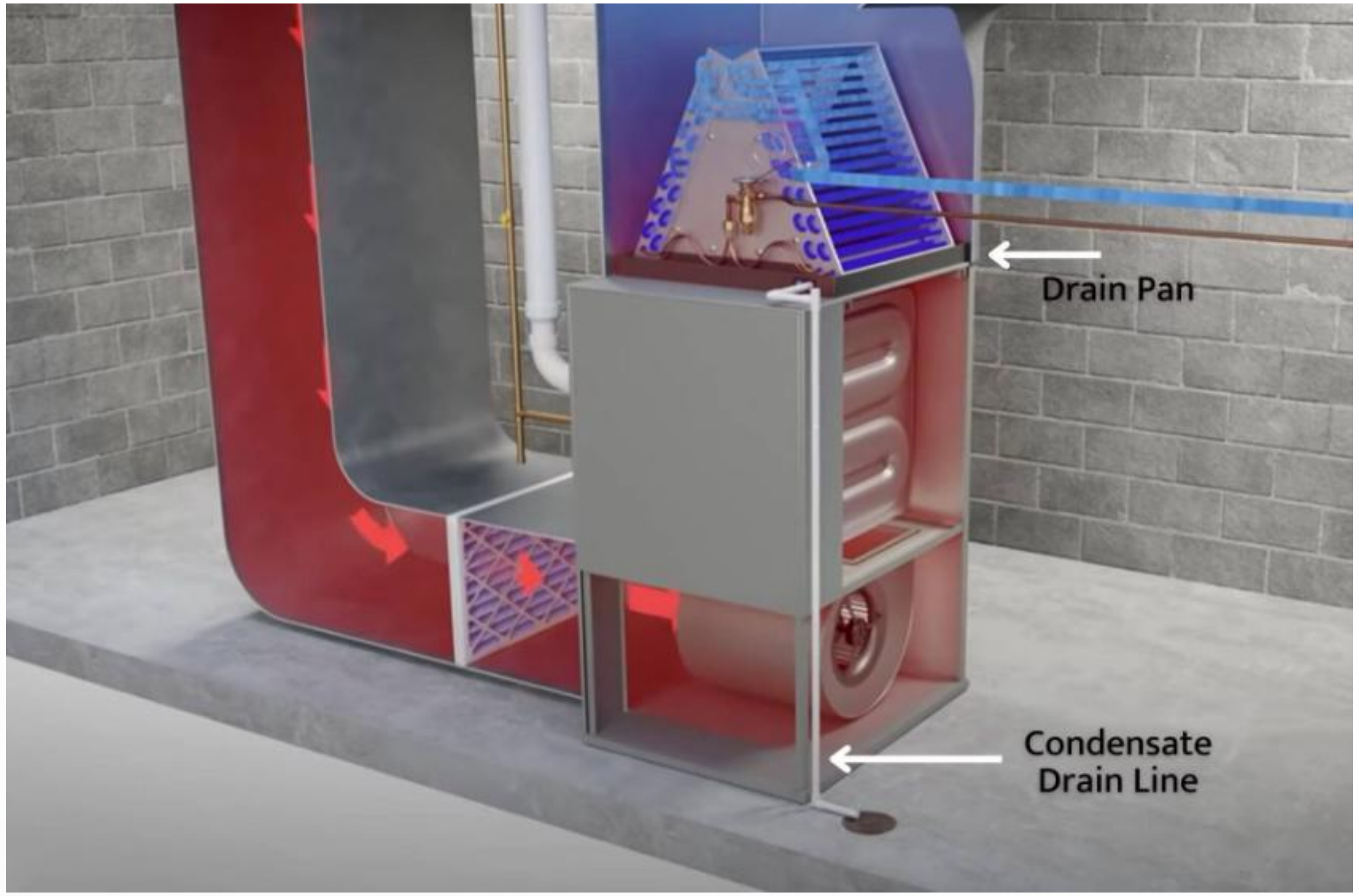
Condensate Properties

The condensate produced is slightly acidic, 3-5 pH, so the choice of materials used in the wetted areas must be suitable. In high temperature areas, most commonly used materials are aluminum alloys and stainless steel; in the low temperature areas, plastics, e.g., UPVC and polypropylene, are most cost effective. The production of condensate also requires the installation of a secondary heat exchanger to remove the heat from the condensate and a condensate drainage system.

Since the final exhaust from a condensing appliance has a lower temperature than the flue gas from a conventional non-condensing appliance, you must use an approved BH venting system.

Condensing Appliance Benefits

- Higher energy efficiency
- Lower operating costs
- Reduced environmental impact
- Recovery of latent heat



Characteristics of a Stable Flame

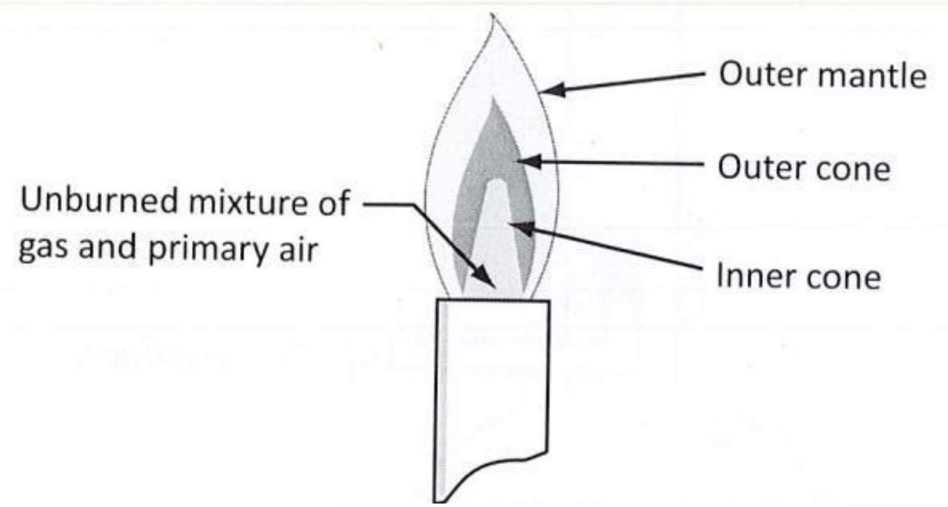
A stable flame is a flame that does not waver, lift off the burner, or flash back into the mixing tube.

Flame colour and shape are characteristics of the flame and as such can only give an indication of flame quality. You must perform a combustion analysis to accurately test flame quality and completeness of combustion, as well as for presence of toxic gases, i.e., carbon monoxide (CO).

Stable Flame Qualities

A stable atmospheric Bunsen burner flame has several colour zones. Each of these zones marks a stage in the burning of gas.

Figure 2-11
Stable Bunsen flame

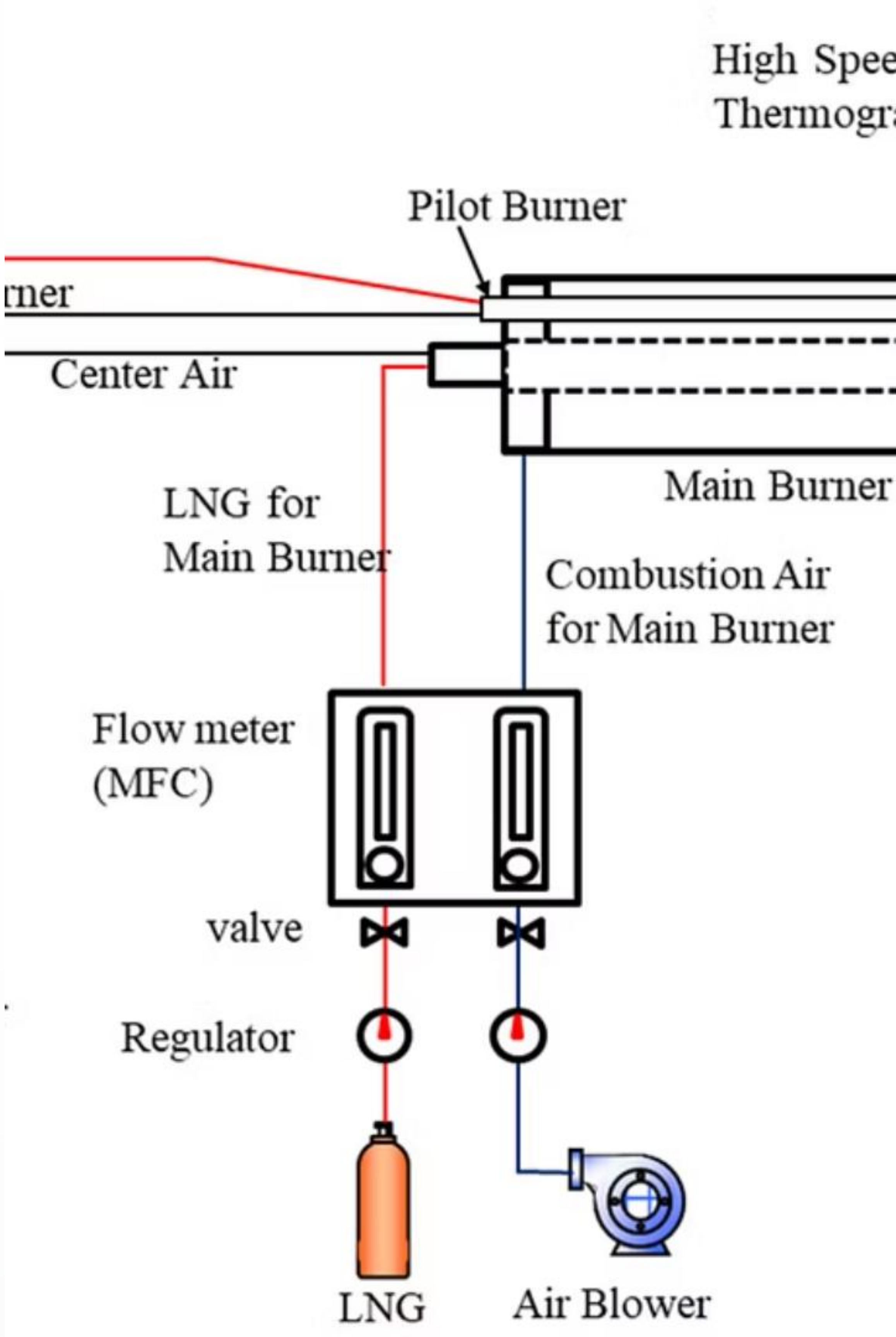


Flame Zones

Color Zone	Description
Inner cone	The inner cone is a thin blue cone on the burner tip. The inner cone marks the first step in the burning process where burning of gas happens to form products such as aldehydes, alcohols, carbon monoxide, and hydrogen. The velocity of the unburned gas-air mixture forms the shape of the inner cone.

Flame Zones Continued

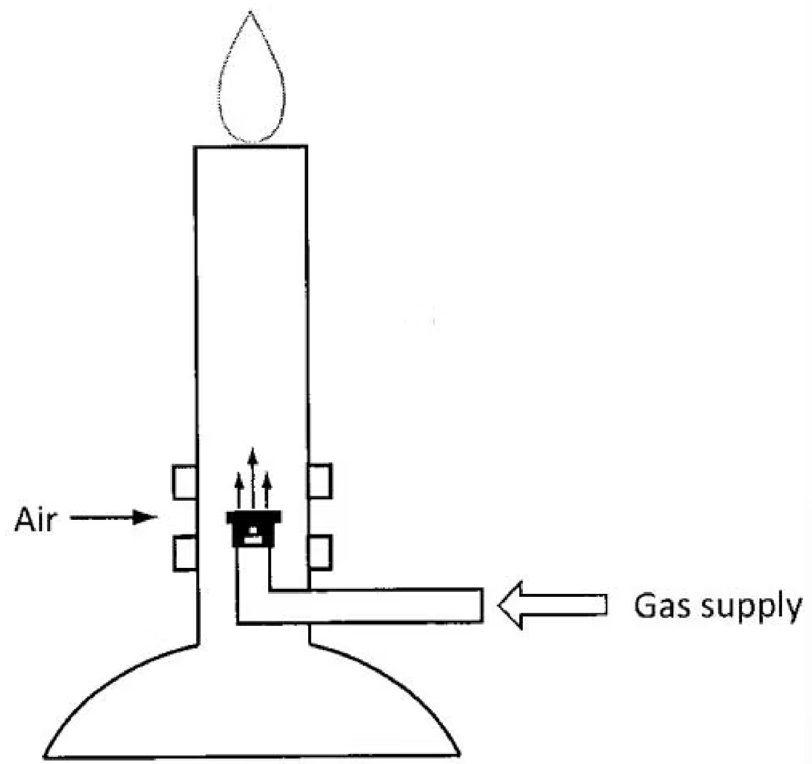
Color Zone	Description
Outer cone	The outer cone is a darker, outer cone that surrounds the inner cone. This is where the secondary air diffuses into the flame. If enough secondary air is present, and other conditions are favourable, the complete burning of products from the inner cone happens here, yielding the final products, carbon dioxide and water vapour.
Outer mantle	The outer mantle is a colourless mantle that surrounds the outer cone. Since complete burning usually happens at the outer cone, there are almost no unburned gases at the outer mantle. This nearly invisible mantle only glows because of the combustion products' high temperature.



Requirements of a Stable Flame

To achieve a stable flame on an atmospheric burner, you need to maintain a fine balance between the flame speed and the flow velocity. Adjusting the primary air supply or the gas flow rates will change the flame speed and flow velocities. A properly adjusted Bunsen-type burner flame is predominantly blue when you properly adjust the primary air.

Figure 2-12
Bunsen flame



Primary Air Supply

The primary air supply sets the flame characteristics. If premixing of the proper amount of primary air with the gas happens, the burner will provide a stable blue flame. Adjustments to the air supply will cause the flame to change shape and colour.

Air Adjustment Effects

Adjustment	Description
Air increase	As the percentage of primary air increases, the flame sharpens and the inner cone gets smaller. When adjustment of the primary air creates a 10% gas-air mixture for natural gas (or a 6% propane-air mixture), the flame reaches its maximum speed. Beyond this point, although adding more primary air increases flow velocity, the flame speed slows down proportionately. The flame will then start to lift off the burner port. Any further increase of primary air supply will eventually cause complete flame liftoff.
Air decrease	When the percentage of primary air decreases, the burning speed decreases since complete combustion requires more secondary air. The flame gets longer, becomes more luminous, and burning speed slows down. Further reduction of the primary air supply will result in the appearance of yellow tips in the flames and the formation of carbon. The flames will become completely yellow if all primary air is shut off.

Air Supply and CO2 Levels

As primary or secondary air supply is decreased, the percentage of CO_2 in the flue gases increases. The theoretical maximum CO_2 produced during complete combustion is 11.8% for natural gas or 13.8% for propane. In practice, when the flue gas percentage of CO_2 reaches 10% or higher for natural gas (11.5% or higher for propane), the air being supplied becomes insufficient, and carbon monoxide may be produced.

Gas Supply

The amount of gas-air mixture passing through a port—called port loading—is also important for creating a stable flame. Burner port-loading is expressed as the number of Btu/h per square inch of port-area.

You can change the port loading by altering either the orifice size or the gas pressure (manifold pressure). For most applications using natural gas, a port loading between 25,000 Btu/h and 30,000 Btu/h per square inch of port area provides a stable flame.

Combustion Quiz Questions

Question 1

What is the specific gravity of liquid propane?

- a) 0.58
- b) 1.54
- c) 7.6
- d) 0.51

Question 2

At atmospheric pressure, propane gas expands at the ratio of ____ when changing from a liquid to a gas.

- a) 1:270
- b) 1:300
- c) 1:600
- d) 1:670

More Quiz Questions

Question 3

What is the flame speed (inches/s) of natural gas?

- a) 11
- b) 10
- c) 12
- d) 9

Question 4

What is the limit of flammability (%) for propane?

- a) 4-15
- b) 2.4-9.5
- c) 3.5-8.5
- d) 3-12

Final Quiz Questions

Question 5

What is the maximum flame temperature in °F (and °C) for propane and natural gas?

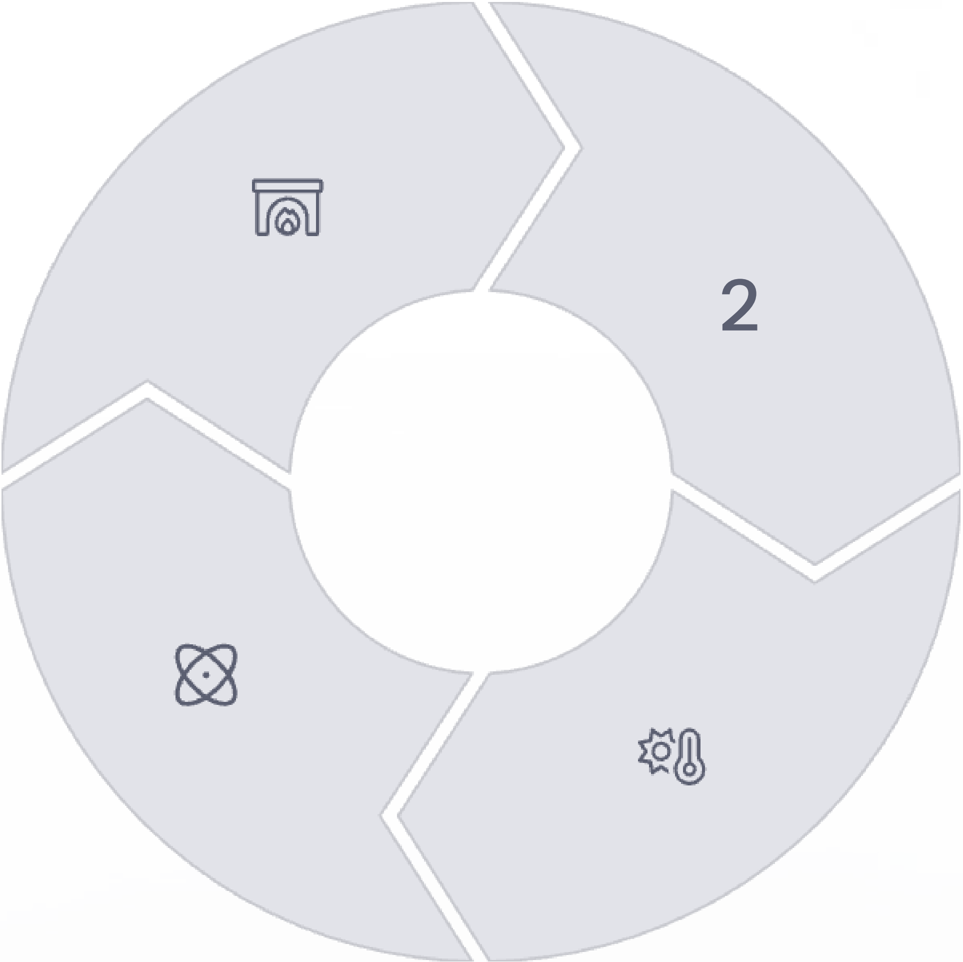
- a) 2,600°F (1,430°C)
- b) 1,600°F (870°C)
- c) 3,600°F (1,980°C)
- d) 4,600°F (2,540°C)

Question 6

_____ is the temperature at which an air-gas mixture initiates and supports combustion. It varies according to the fuel gas used.

- a) Flame temperature
- b) Limits of flammability
- c) Ignition temperature

Combustion Triangle Review



Fuel

Natural gas, propane, or other hydrocarbon fuel

Oxygen

Obtained from surrounding air

Heat

Sufficient to reach ignition temperature

Chemical Chain Reaction

Sustains the combustion process

The combustion process requires all four elements to be present in the proper proportions. Removing any one element will stop the combustion process.

Advanced Combustion Elements Review

Time

Duration for complete burning

Temperature

Heat level for efficient combustion

Turbulence

Proper mixing of air and fuel

These three elements work together to ensure efficient and complete combustion. Proper time allows for complete burning, adequate temperature ensures the reaction continues, and turbulence ensures thorough mixing of fuel and air.

Types of Combustion Review

Perfect Combustion

Theoretical ideal with exact air-fuel ratio

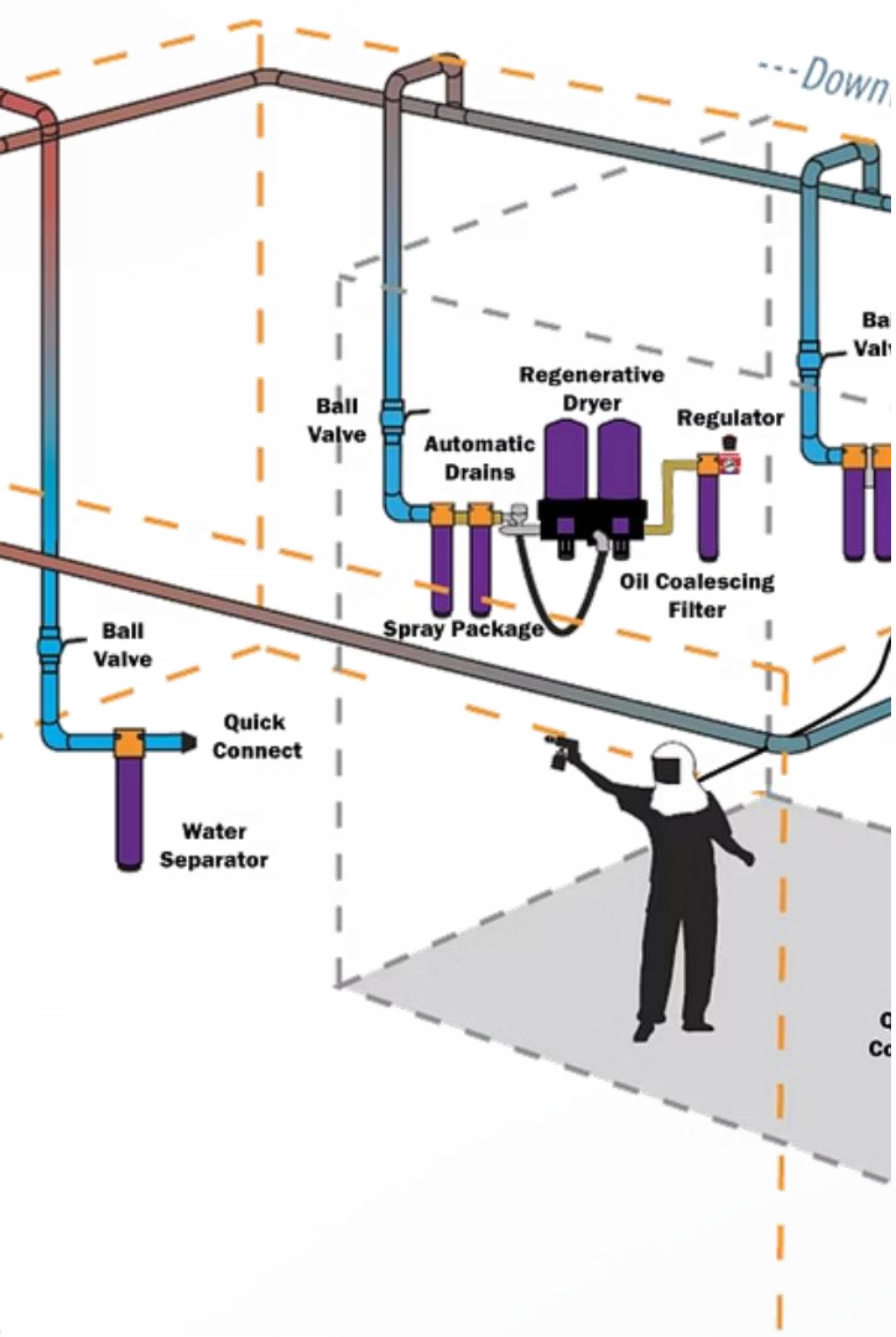
Complete Combustion

All fuel burned with excess air

Incomplete Combustion

Insufficient oxygen creating harmful byproducts

Understanding these different types of combustion is essential for gas technicians to ensure safe and efficient operation of gas appliances. While perfect combustion is theoretical, complete combustion is the practical goal, and incomplete combustion must be avoided due to the production of harmful substances like carbon monoxide.



Air Supply Categories Review

Primary Air

Mixed with fuel before ignition

Typically 1/3 of theoretical air requirement

Controls initial flame characteristics

Secondary Air

Mixes at the point of combustion

Typically 2/3 of theoretical air requirement

Completes the combustion process

Excess Air

Additional air beyond theoretical requirement

Ensures complete combustion

Must be minimized to maintain efficiency

Dilution Air

Cools vent gases

Controls draft in the venting system

Only needed with draft control devices

Psychrometric Calculations

Room height:	8	ft
Enter Area as:	Area	
Area:	1821	ft^2
Room Volume:	14568	ft^3

Air Supply Calculations Review

10 ft^3

Combustion Air

Per 1,000 Btu input

5 ft^3

Excess Air

Per 1,000 Btu input

15 ft^3

Dilution Air

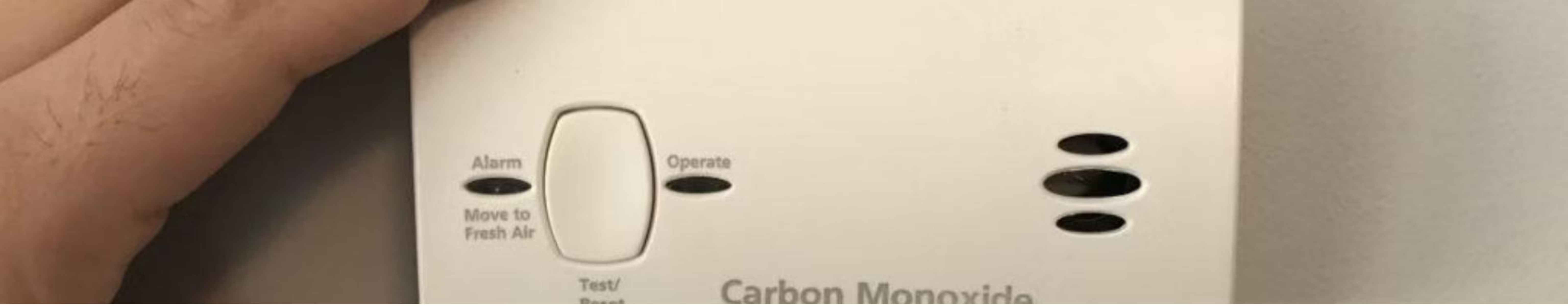
Per 1,000 Btu input

30 ft^3

Total Air

Per 1,000 Btu input

These calculations are essential for determining the proper air supply for gas appliances. The total air requirement of 30 cubic feet per 1,000 Btu input ensures safe and efficient operation.



Causes of Incomplete Combustion Review

Insufficient Flame Temperature

When flame temperature drops below ignition point

Cracked Heat Exchanger

Allows improper air mixing in combustion chamber

Blocked Venting

Prevents proper air flow and exhaust

Negative Air Pressure

Disrupts proper draft and combustion air supply

Flame Characteristics Review

Stable Flame Zones

- Inner cone - Initial burning, blue in color
- Outer cone - Secondary air mixing, darker blue
- Outer mantle - Complete combustion, nearly colorless

A properly adjusted flame should be predominantly blue with well-defined zones. Yellow flames indicate incomplete combustion and potential carbon monoxide production.

Flame Adjustments

- Increasing air - Sharpens flame, may cause lifting
- Decreasing air - Lengthens flame, may cause yellow tips
- Optimal balance - Stable blue flame with proper zones

Condensing Appliances Review

Condensing Process

Flue gas condensation involves cooling flue gases below the water dew point to recover latent heat from water vapor condensation. This process can increase efficiency by 10-20% compared to non-condensing appliances.

Special Requirements

- Corrosion-resistant materials (aluminum, stainless steel)
- Secondary heat exchanger
- Condensate drainage system
- Approved BH venting system

High Altitude Considerations

Pressure Changes

For every 2,000 ft rise in elevation, barometric pressure reduces by approximately 1 psia from the sea level pressure of 14.73 psia.

Effects on Combustion

- Gas becomes less dense at higher altitudes
- Gas flows more easily through orifices
- Input-to-oxygen ratio becomes unbalanced
- Adjustments needed for proper combustion

Carbon Monoxide Measurement

Air-Free CO Calculation

CO air free = 20.9 ÷ (20.9 - O_2 measured) × measured CO ppm

This calculation compensates for dilution effects when measuring carbon monoxide levels in combustion products.

Alternative Method

CO (air-free) = CO (measured) × CO_2 (ultimate) ÷ CO_2 (measured)

Where:

- CO_2 (ultimate) = 11.8% for natural gas
- CO_2 (ultimate) = 13.8% for propane

Port Loading

The amount of gas-air mixture passing through a port—called port loading—is important for creating a stable flame. Burner port-loading is expressed as the number of Btu/h per square inch of port-area.

Factors Affecting Port Loading

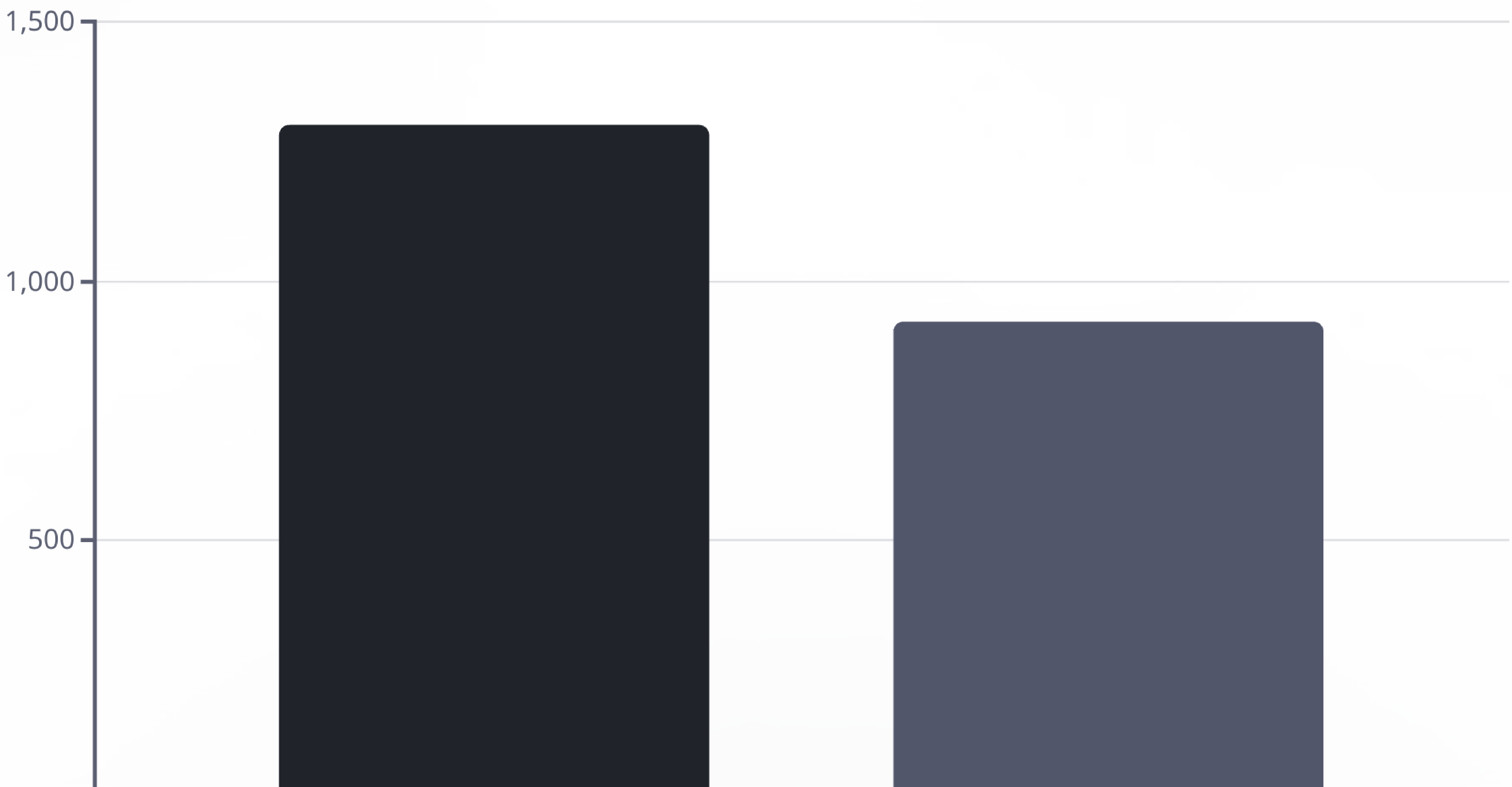
- Orifice size
- Gas pressure (manifold pressure)
- Port area

Optimal Port Loading

For most applications using natural gas, a port loading between 25,000 Btu/h and 30,000 Btu/h per square inch of port area provides a stable flame.

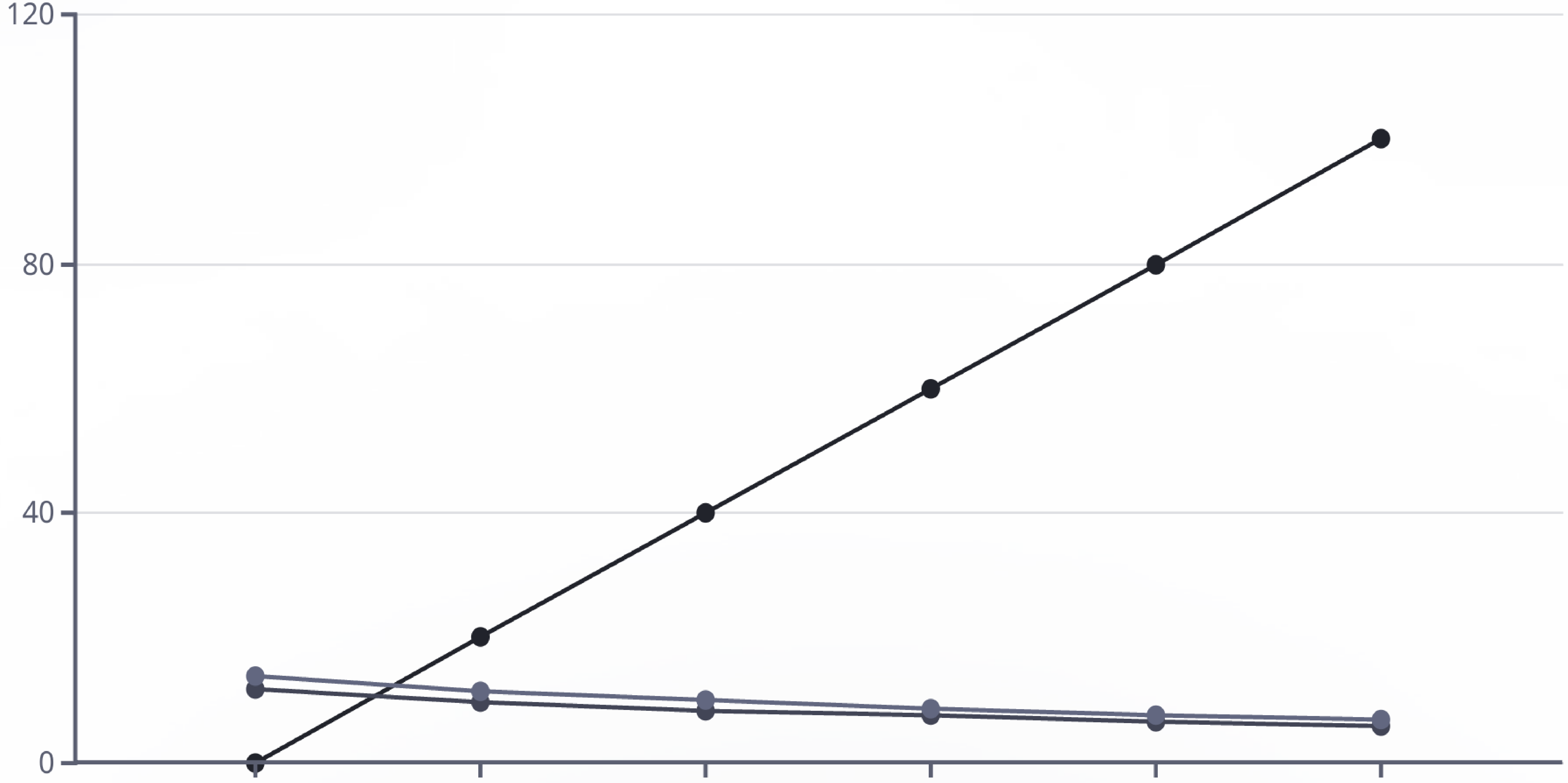
Proper port loading helps prevent issues like flame lifting, flashback, and incomplete combustion.

Ignition Temperatures Comparison



Air Requirements for Different Appliances

CO2 Levels in Flue Gases



Combustion Testing Equipment

Combustion Analyzer

Measures O2, CO2, CO, and other combustion parameters to assess combustion efficiency and safety

Draft Gauge

Measures the pressure differential in venting systems to ensure proper draft

Smoke Pencil

Used to detect air movement and check for proper draft at draft hoods and relief openings

Proper testing equipment is essential for gas technicians to verify safe and efficient combustion. These tools help identify potential issues before they become safety hazards.

Combustion Safety Summary

Ensure proper air supply

Verify that combustion, excess, and dilution air requirements are met

Monitor flame characteristics

Look for stable, blue flames with proper zones and no lifting or yellow tips

Perform combustion analysis

Regularly test for CO, CO_2, and O_2 levels to verify complete combustion

Check venting systems

Ensure vents are clear and properly sized for the appliance

Consider altitude effects

Make appropriate adjustments for high-altitude installations

CSA Unit 3

Chapter 3
Gas Hazards in Gas Technician Work

A gas technician/fitter must know how to investigate, detect, and remedy gas leaks, incomplete combustion, and the effects of corrosive vapours on gas-fired appliances and equipment in a safe and efficient manner. This presentation covers combustible gas indicators, gas leak investigation procedures, incomplete combustion detection, and the effects of corrosive vapors on gas equipment.

Purpose and Objectives

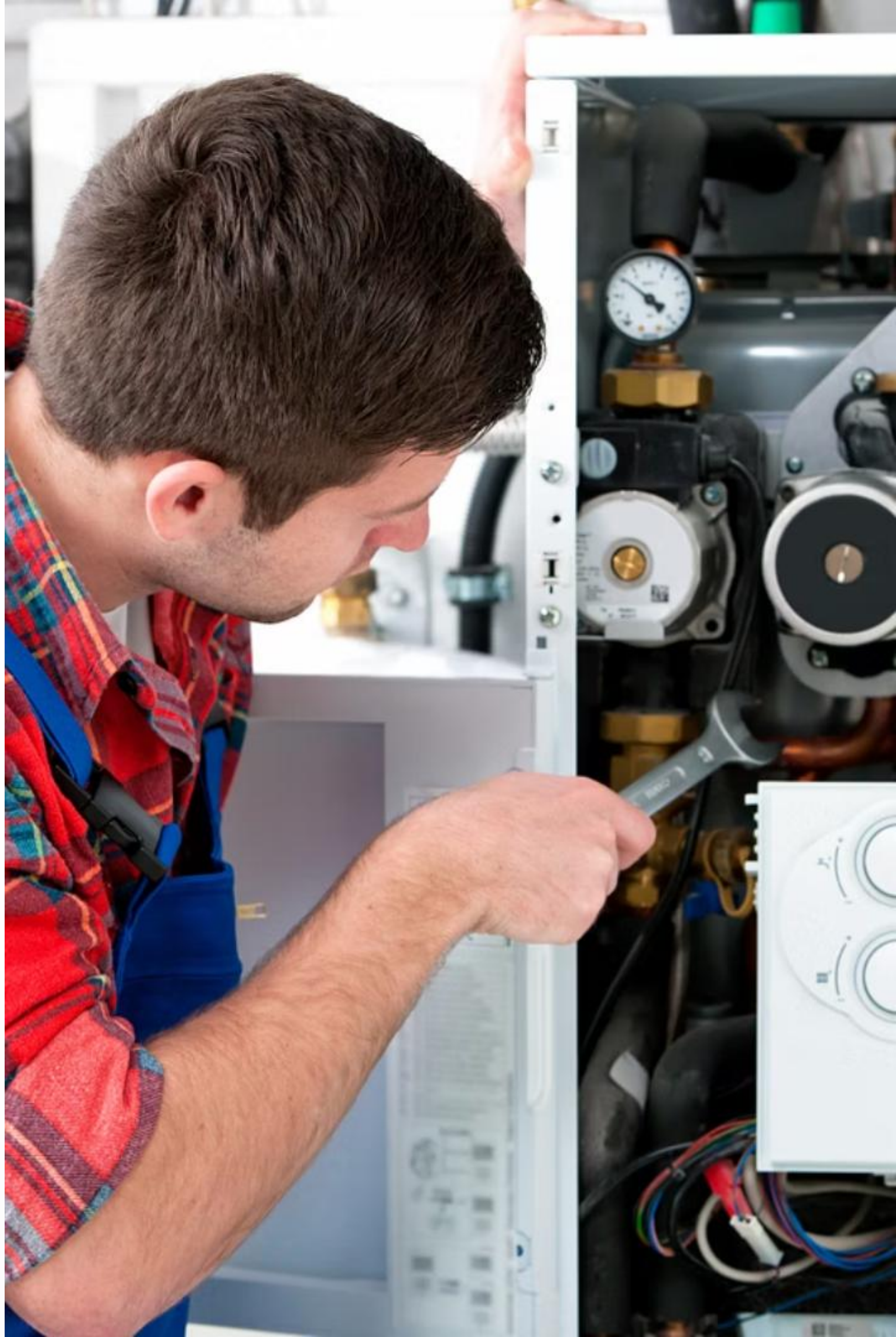
Purpose

A gas technician/fitter must know how to investigate, detect, and remedy gas leaks, incomplete combustion, and the effects of corrosive vapours on gas-fired appliances and equipment in a safe and efficient manner.

Objectives

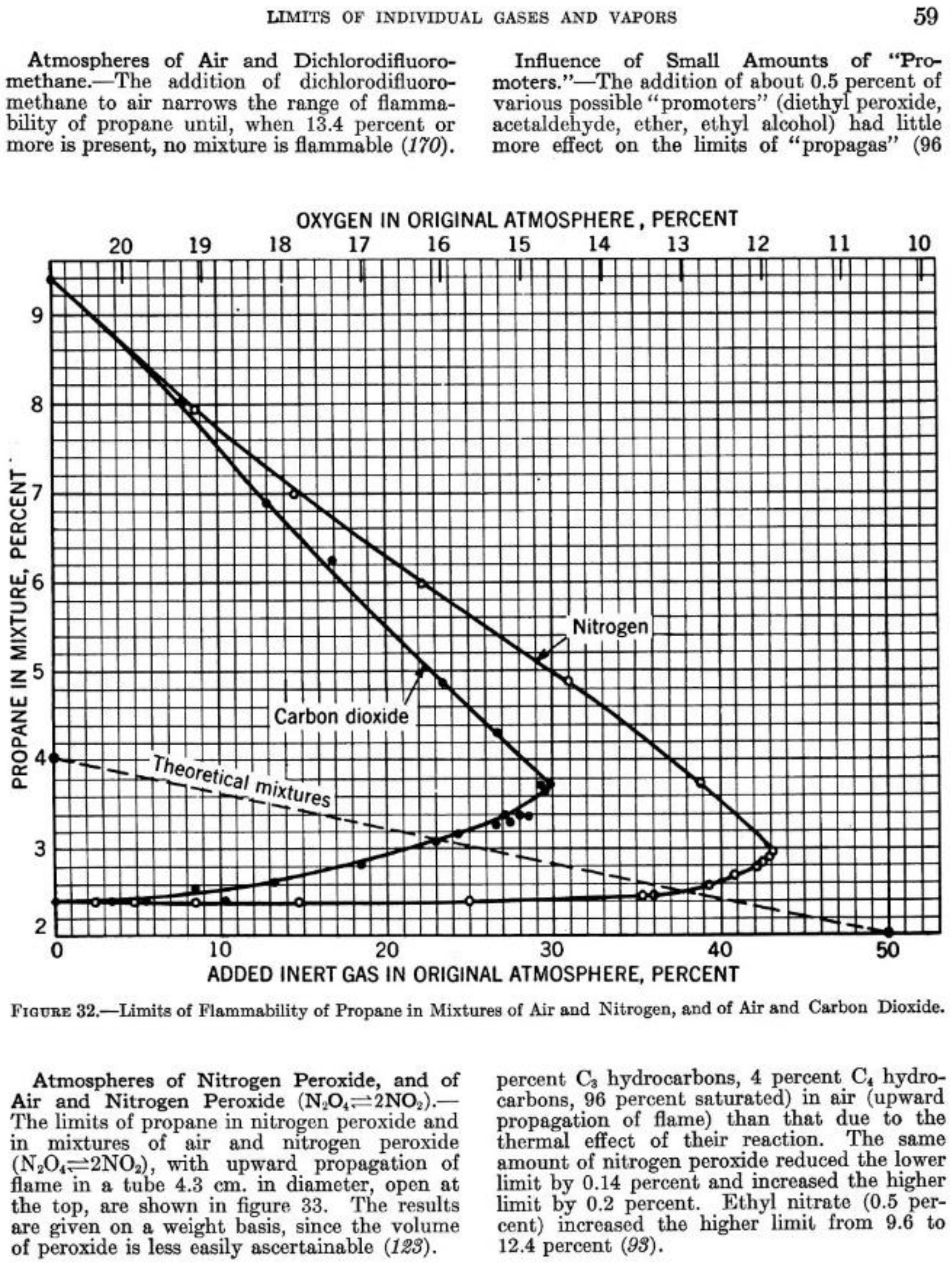
At the end of this Chapter, you will be able to:

- identify combustible gas indicators
- describe how to investigate gas leaks
- describe how to investigate incomplete combustion
- describe the effects of corrosive vapours



Key Terminology

Term	Abbreviation (symbol)	Definition
Combustible gas indicator	CGI	Instrument for detecting gas-air (or vapour-air) mixtures to determine the explosive levels of the mixture
Lower explosive limit	LEL	The lowest concentration (percentage) of a gas or a vapour in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat)
Upper explosive limit	UEL	The highest concentration (percentage) of a gas or a vapour in air capable of producing a flash of fire in presence of an ignition source (arc, flame, and heat)


LIMITS OF INDIVIDUAL GASES AND VAPORS 59

Atmospheres of Air and Dichlorodifluoromethane.—The addition of dichlorodifluoromethane to air narrows the range of flammability of propane until, when 13.4 percent or more is present, no mixture is flammable (*170*).

Influence of Small Amounts of "Promoters."—The addition of about 0.5 percent of various possible "promoters" (diethyl peroxide, acetaldehyde, ether, ethyl alcohol) had little more effect on the limits of "propagas" (96

FIGURE 32.—Limits of Flammability of Propane in Mixtures of Air and Nitrogen, and of Air and Carbon Dioxide.

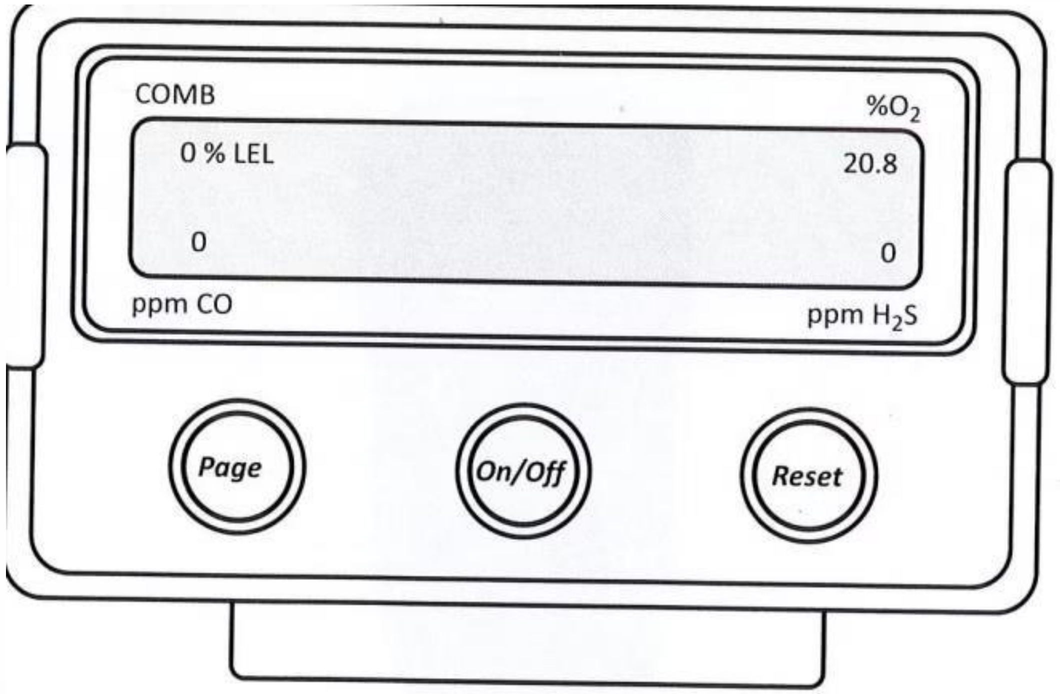
Atmospheres of Nitrogen Peroxide, and of Air and Nitrogen Peroxide ($N_2O_4 \rightleftharpoons 2NO_2$).—The limits of propane in nitrogen peroxide and in mixtures of air and nitrogen peroxide ($N_2O_4 \rightleftharpoons 2NO_2$), with upward propagation of flame in a tube 4.3 cm. in diameter, open at the top, are shown in figure 33. The results are given on a weight basis, since the volume of peroxide is less easily ascertainable (*123*).

percent C_3 hydrocarbons, 4 percent C_4 hydrocarbons, 96 percent saturated) in air (upward propagation of flame) than that due to the thermal effect of their reaction. The same amount of nitrogen peroxide reduced the lower limit by 0.14 percent and increased the higher limit by 0.2 percent. Ethyl nitrate (0.5 percent) increased the higher limit from 9.6 to 12.4 percent (*93*).

Combustible Gas Indicators (CGI)

A combustible gas indicator (CGI) is an instrument for detecting gas-air (or vapour-air) mixtures to determine the explosive levels of the mixture.

A combustible gas indicator can save lives. A gas technician/fitter should know how to use it and make sure that it is accurate. A gas technician/fitter must become thoroughly familiar with the operation and limitations of the indicator and should be satisfied that the instrument is in proper operating condition.



Solid-state combustible gas indicator

General Guidelines for CGI Use

Audio Alarms

Audio alarms correspond to a factory-set parts per million (ppm) level of gas. You can shut off the alarm in certain circumstances to avoid causing distress to the public.

Calibration

You should perform calibration regularly and according to manufacturer's instructions.

Accessories

Some CGI Units come with probes and hoses (including pumps and battery packs) for remote sampling. Always use the appropriate accessories when required.

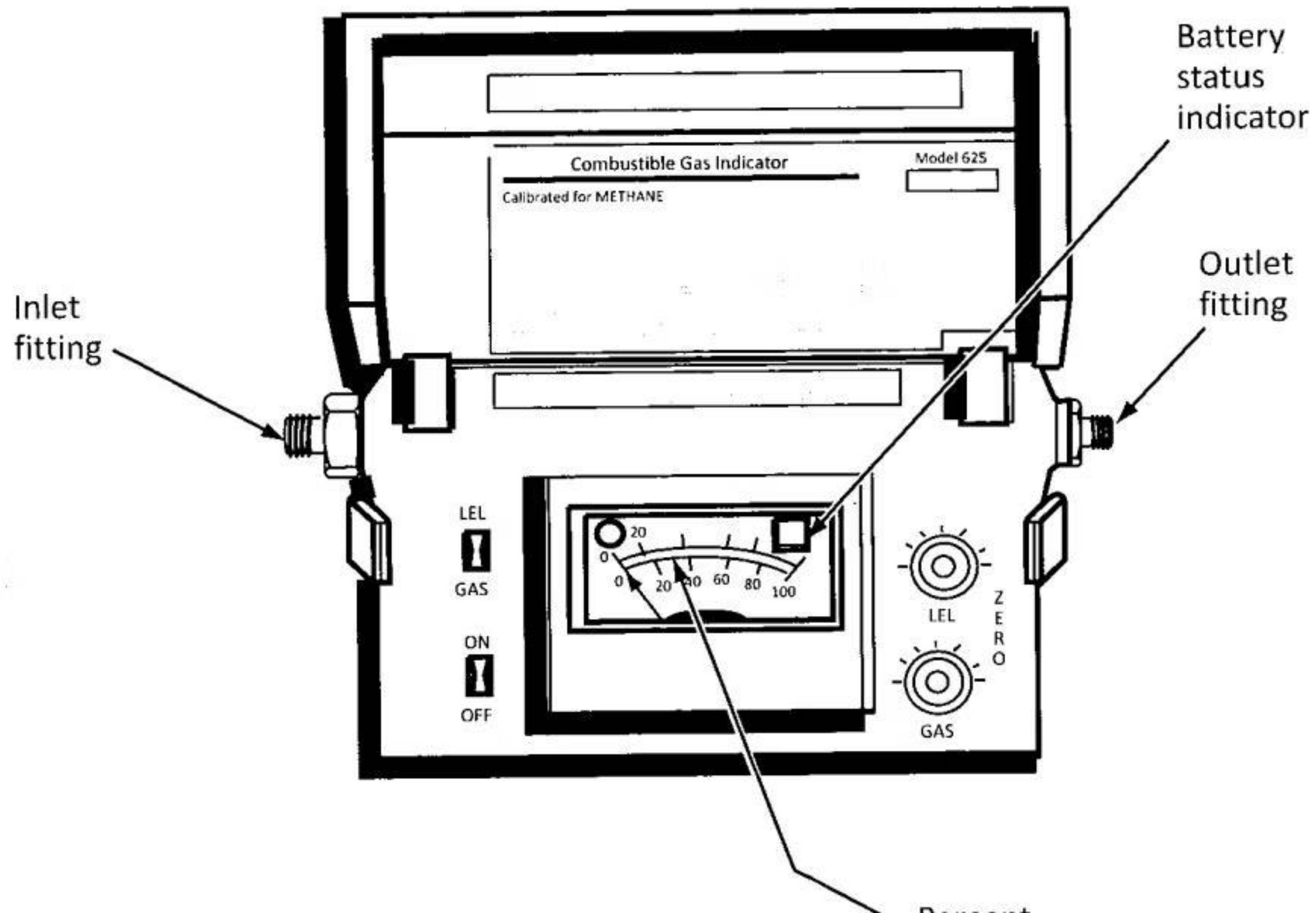
Types of Combustible Gas Indicators

Solid-State Indicator

The solid-state CGI is a small, light hand-held Unit. It comes with a light-emitting diode (LED) display, a digital readout, or an analogue dial indicator, and an audible alarm.

Some models are adjustable to detect several gases at one time. The readout indicates the gas level in ppm or percent of lower explosive limit (LEL).

This type can sense gases at as little as 2–3 ppm of gas in air and is more commonly used and much more sensitive than the filament type.



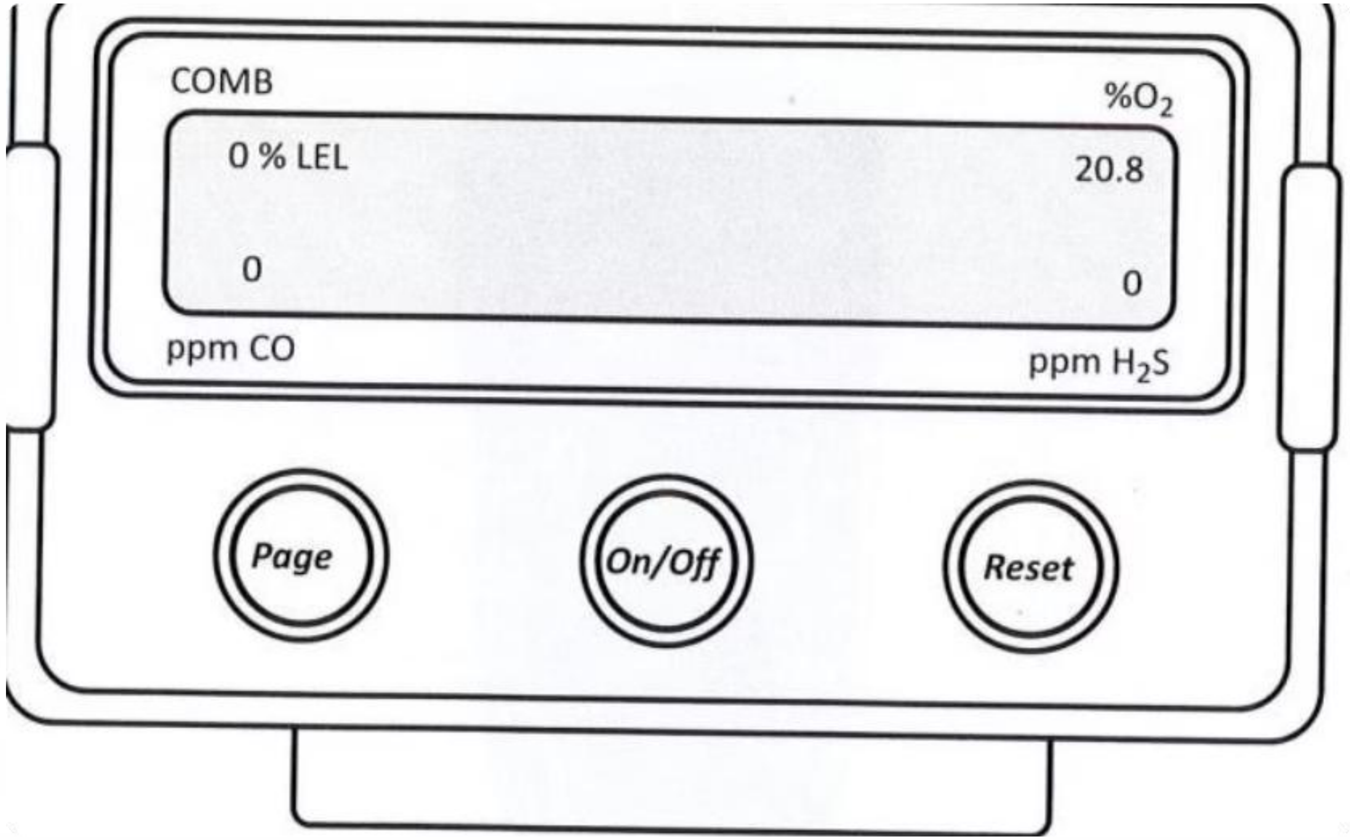
Filament-Type Indicator

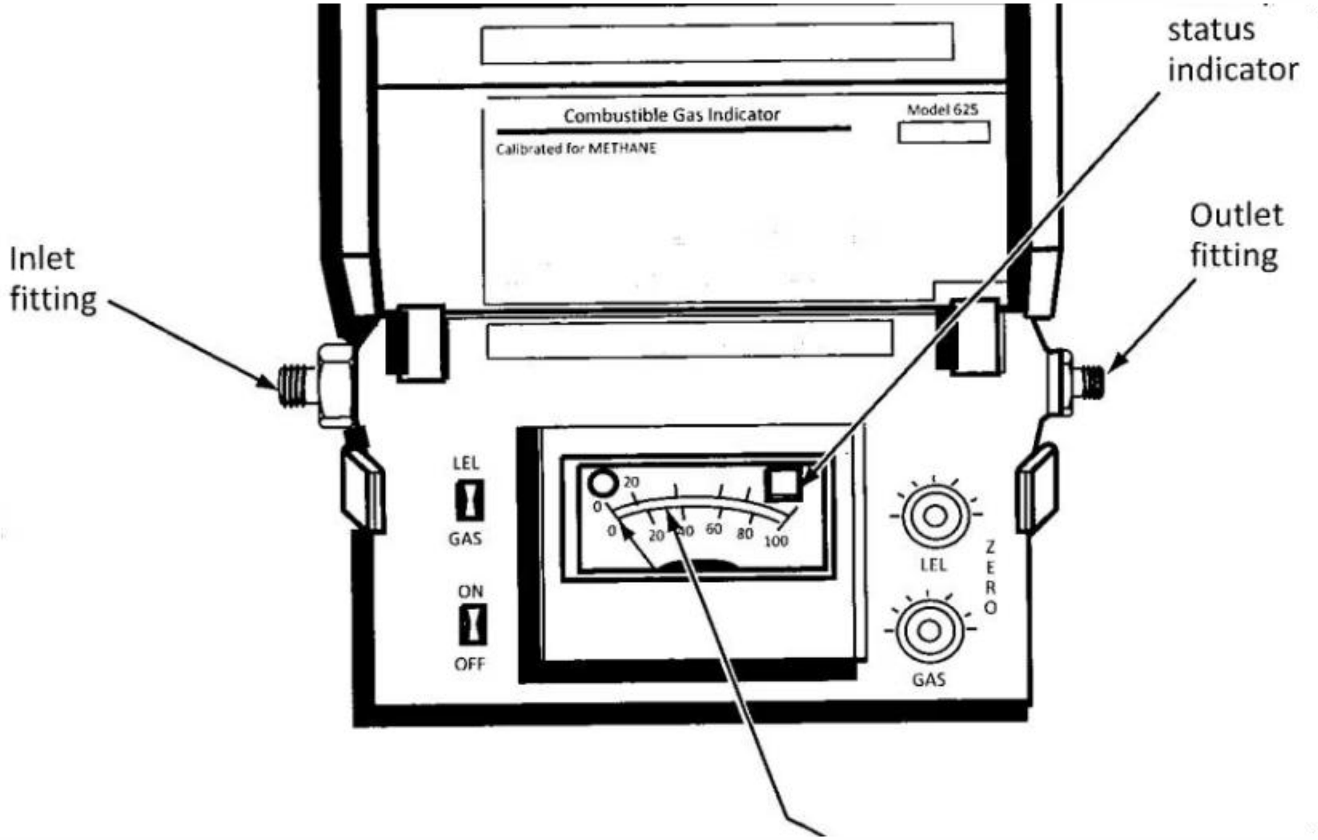
The filament-type indicator works on the principle of catalytic combustion. The meter draws the air-and-gas mixture through the sampling inlet and across the detector filament.

The filament consists of a catalytic material that ignites the mixture at a low temperature and then registers the percent of explosive limits on a dial.

Be aware that the filament type is not as sensitive as the solid-state type and must be purged manually before sampling.

Solid-State vs. Filament-Type Indicators





Solid-State Indicator

More sensitive, can detect gases at 2-3 ppm. Features LED display, digital readout, or analogue dial with audible alarm. Some models can detect several gases simultaneously.

Filament-Type Indicator

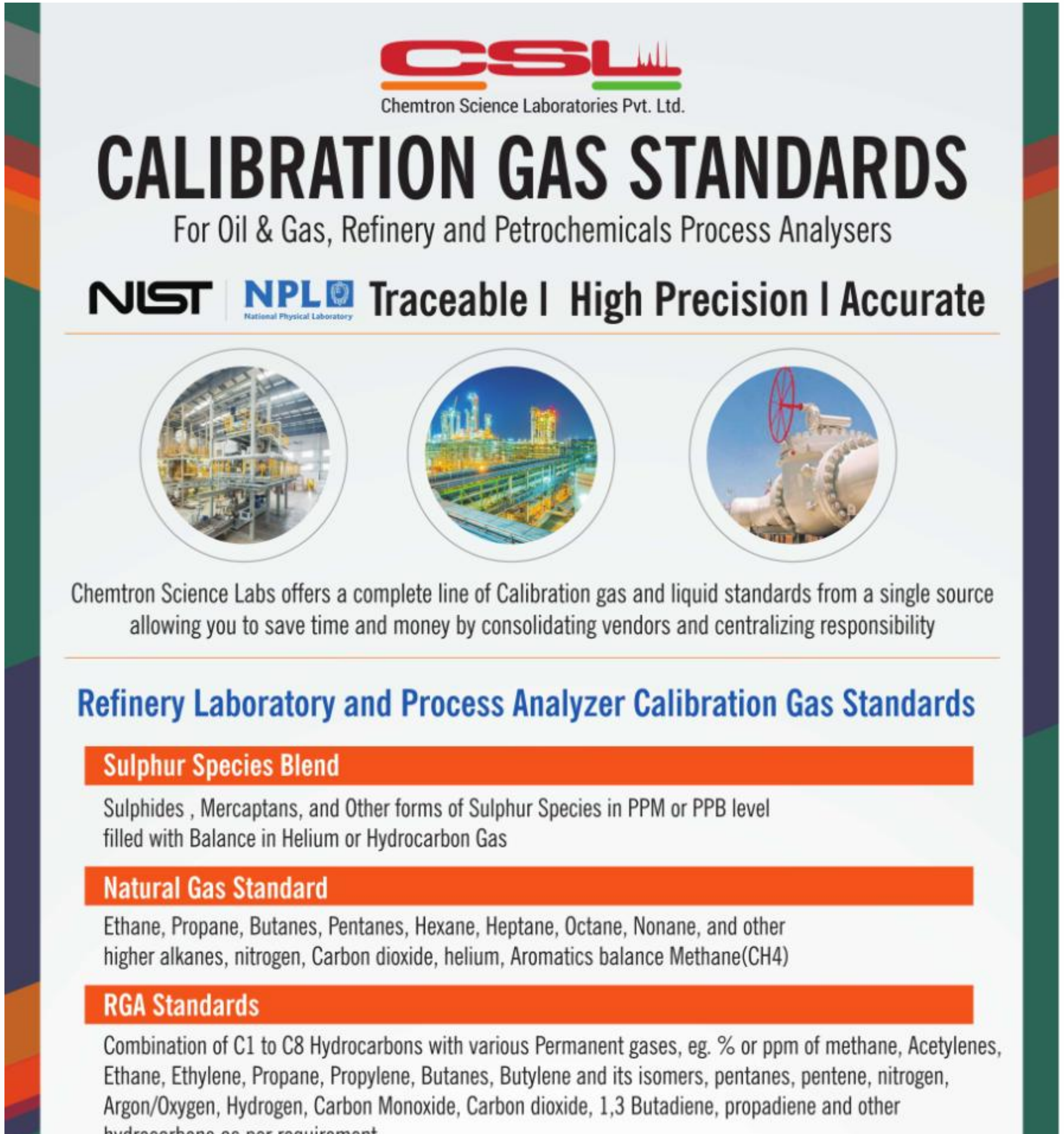
Works on catalytic combustion principle. Less sensitive than solid-state type. Must be purged manually before sampling. Draws air-gas mixture across detector filament to register percent of explosive limits.

Conversion Charts for CGI

Each indicator is calibrated to a specific gas, and conversion charts are available if you wish to use to check for other gases or vapours.

Because each manufacturer makes many different models, you should be sure you have the correct instrument for the job at hand. An instrument calibrated for a known gas at the manufacturer's plant (a standard calibration) is usually most suitable.

However, a CGI that is calibrated for one specific gas (such as hydrogen or methane) may not read correctly on other substances. Therefore, make sure you have a CGI that can read the gas you are testing for.



Sample of Gases to be Tested

Fuel Gases

- Natural gas
- Propane
- Butane
- Methane

Industrial Gases

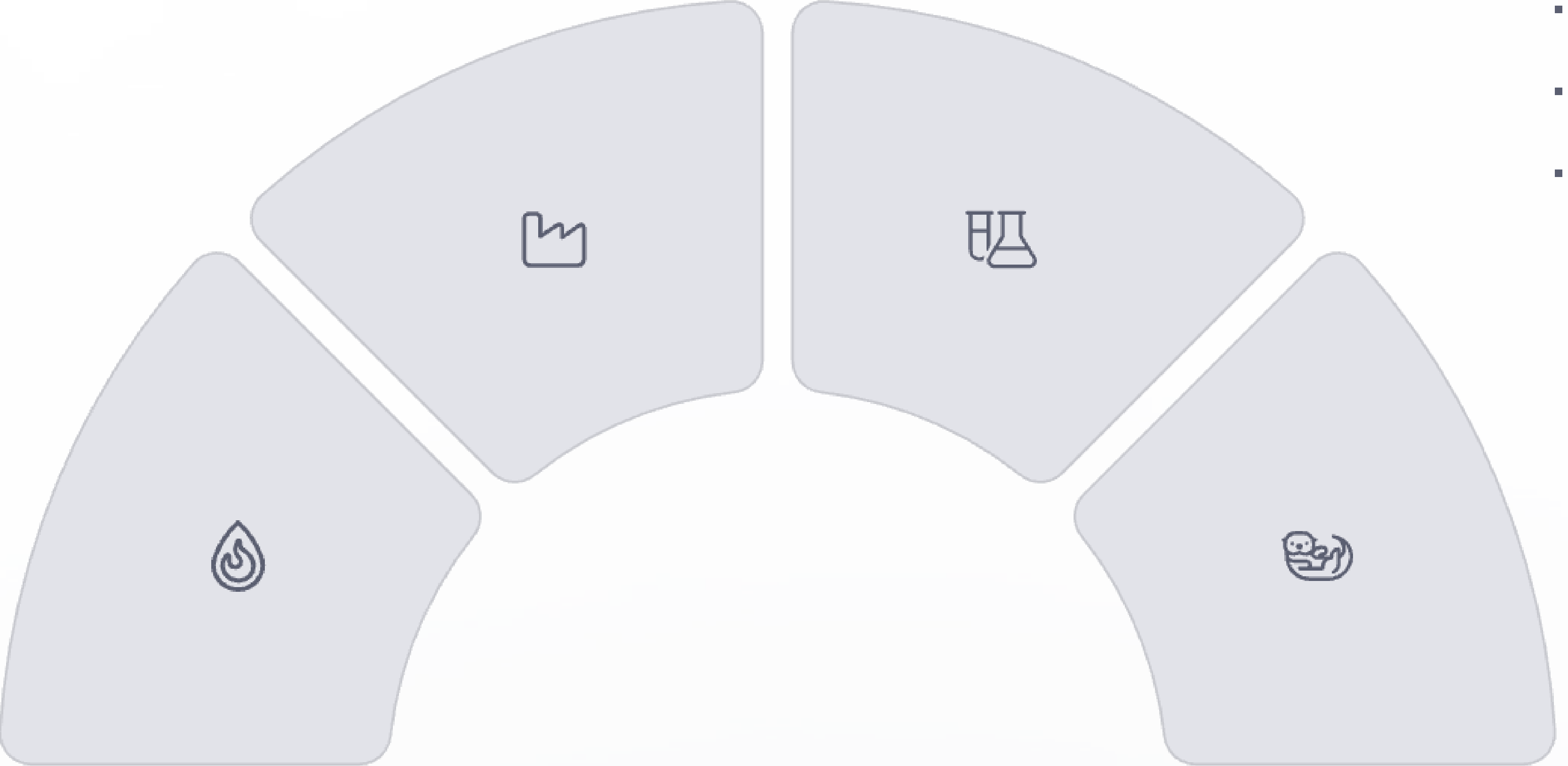
- Industrial solvents
- Hydrogen sulphide
- Ammonia
- Carbon monoxide

Chemical Compounds

- Acetone
- Alcohol
- Lacquer thinners
- Gasoline

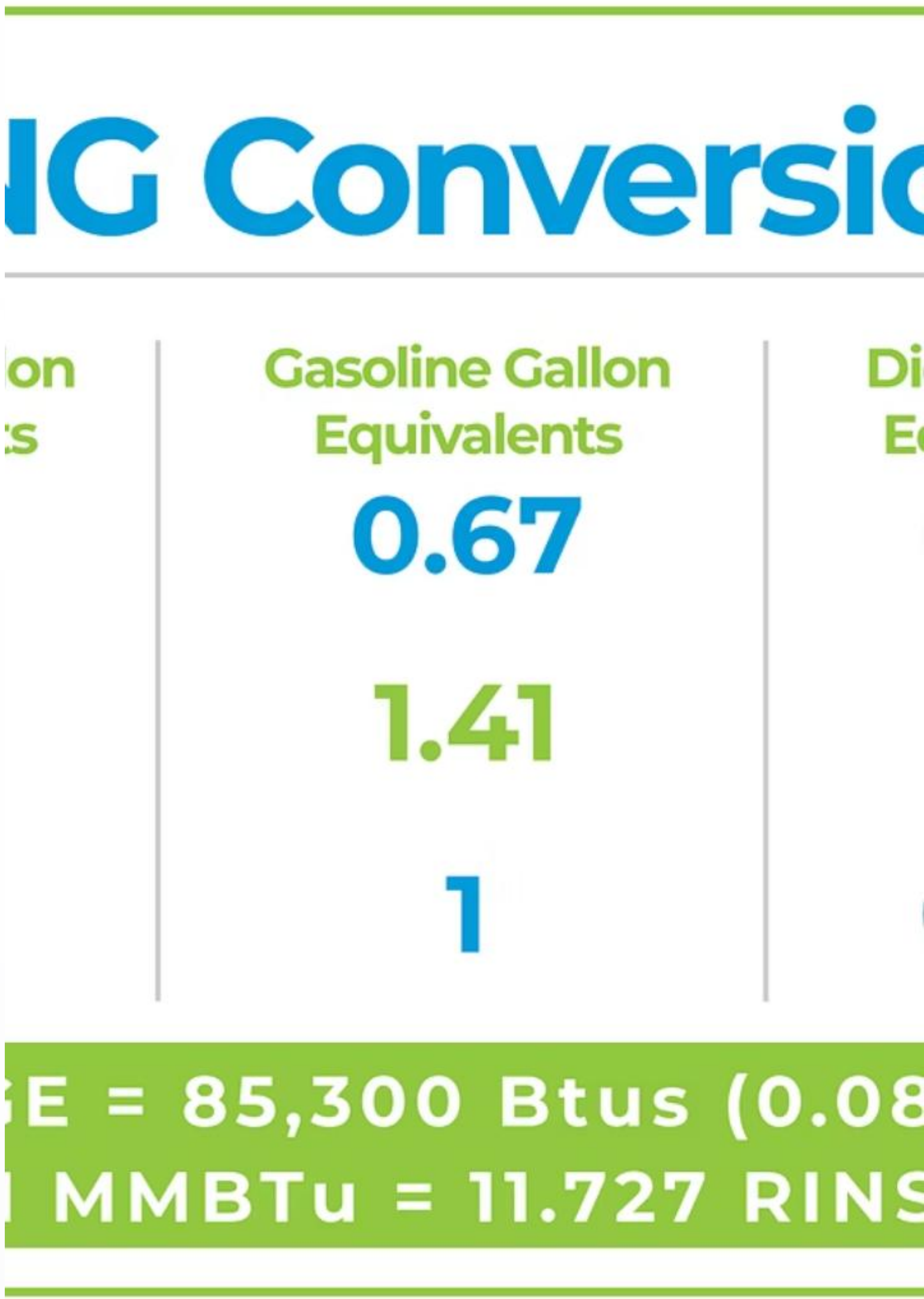
Other Substances

- Jet fuel
- Naphtha
- Refrigerant
- Smoke
- Steam



Conversion Chart Example

Combustible gas	Multiply % LEL reading by
Acetone	1.1
Acetylene	0.7
2,3 Dimethylpentane	1.2
Ethane	0.7
Gasoline (unleaded)	1.3
Hydrogen	0.6
Methane	0.5
Methanol	0.6
n-Pentane	1.0
Propane	0.8



CGI Accessories and Best Practices

Do...

- When probing overhead, use a non-conducting probe in case you touch a "hot" electrical circuit
- Use a liquid trap in the sampling system when sampling enclosed vessels that may contain liquids
- Use the hoses provided
- Follow the proper instructions for the care and maintenance of your CGI
- Use the supplied accessories
- Check the battery periodically
- Be aware of how temperature and pressure can affect the explosive range readings
- Turn the indicator off when not in use

Don't...

- Remove flashback arresters if the CGI has them
- Use the indicator for sampling gasoline vapours containing TEL (tetraethyllead), unless the indicator has received approval for this application
- Let the sampling hose or probe reach into a liquid

Calibration of CGI

Calibration Test Kits

For most Units, calibration test kits are available. Periodically check the indicator calibration to ensure the indicator is working correctly.

Manufacturer's Manual

Refer to the manufacturer's manual for correct settings. Always read the instruction book that accompanies each instrument.

Complete Instructions

In the manual you will find complete instructions, possible troubles and remedies, and an exploded diagram of all parts with their stock number.

Investigating Gas Leaks: Safety First

First and foremost, when responding to a gas leak call, your concern is safety. The following information about what to do in the event of a gas leak call is based on safety first.

Remember that you can replace property, but not lives!

Gas Leak Response Flowchart

ON A GAS LEAK CALL

1 PREPARE
Prepare combustible gas indicator and collect other tools

2 KNOCK
Don't ring the doorbell

3 COMMUNICATE
Advise occupant not to smoke or use electrical units

4 TAKE A READING
- Natural gas: investigate high locations
- Propane: investigate low locations

Margin of safety

Reading below LEL

5 MAKE SAFE
- Direct occupant(s) outside
- Ventilate up and out

6 CUT OFF IGNITION SOURCES
- Open master breaker at electrical panel
- Close manual valve on gas appliances

7

Explosion potential!

Reading near or above LEL

5 MAKE SAFE IMMEDIATELY
- Evacuate occupant(s) from the building—including yourself!
- ***Do not cross-ventilate***
- Turn off gas riser valve, or propane cylinder/tank service valve
- Using a remote telephone, call police, fire department, and gas utility (supplier)

Step 1: Prepare for Gas Leak Investigation

1. Prepare the combustible gas indicator
   - Purge it in clean air (if required)
   - Switch it on
2. Bring useful equipment
   - Leak detection soap solution (bubbles)
   - Pressure gauge or manometer
   - Safety flashlight (Class 1)
   - Pipe wrench

Step 2 & 3: Knock and Communicate

Step 2: Knock

When arriving at the premises with the suspected leak, knock on the door. Do not use the doorbell, as this could cause ignition if gas is present in the area of the doorbell's power source.

Step 3: Communicate

- Identify yourself
- Inquire about the situation to obtain further facts
- Inform them:
  - not to smoke
  - not to use any appliances
  - not to operate any electrical switch
  - not to use any phone, pager, or cell phone in the building

Step 4: Take a Reading

Natural Gas

If the natural gas appliances are in the basement, a good place to test is in the basement stairwell, immediately after you enter the building, near the top of the door.

Natural gas is lighter than air, with a specific gravity of approximately 0.60. Consequently, it tends to rise or follow any path of least resistance.

Propane

If the supply is propane, a good place to begin testing for propane leaks is at floor level.

The specific gravity of propane is greater than that of air, it is heavier and will tend to collect at lower levels.

CGI Reading Interpretation

Reading Above the LEL

If the CGI reading is above the LEL, which indicates that the concentration of fuel is near or above the explosive limits:

- There is no time to waste
- You must make safe immediately and calmly
- Follow the steps for when the reading is above the LEL

Reading Well Below the LEL

If the CGI reading is well below the LEL, which is 4% for natural gas and 2.4% for propane:

- There is a problem, but you have some margin for safety
- Proceed with caution
- A reading below LEL indicates that the immediate area you are in has a margin of safety; however, the immediate area of the leak could be above the LEL
- Follow the steps for when the reading is well below the LEL

Step 5: Make Safe When Reading is Above LEL

Evacuate the occupant(s) - including you!

In larger buildings, you should notify and instruct the building manager to activate the emergency evacuation plan. Stay calm, but positive, when directing people.

Do not cross-ventilate

When gas concentrations are near the explosive limits, cross-ventilating is dangerous—it is possible that you might move potentially explosive concentrations of gas to a possible source of ignition. For this reason, it is not considered safe practice to cross-ventilate when the UEL reading is at a critical point.

Turn off gas supply on your way out

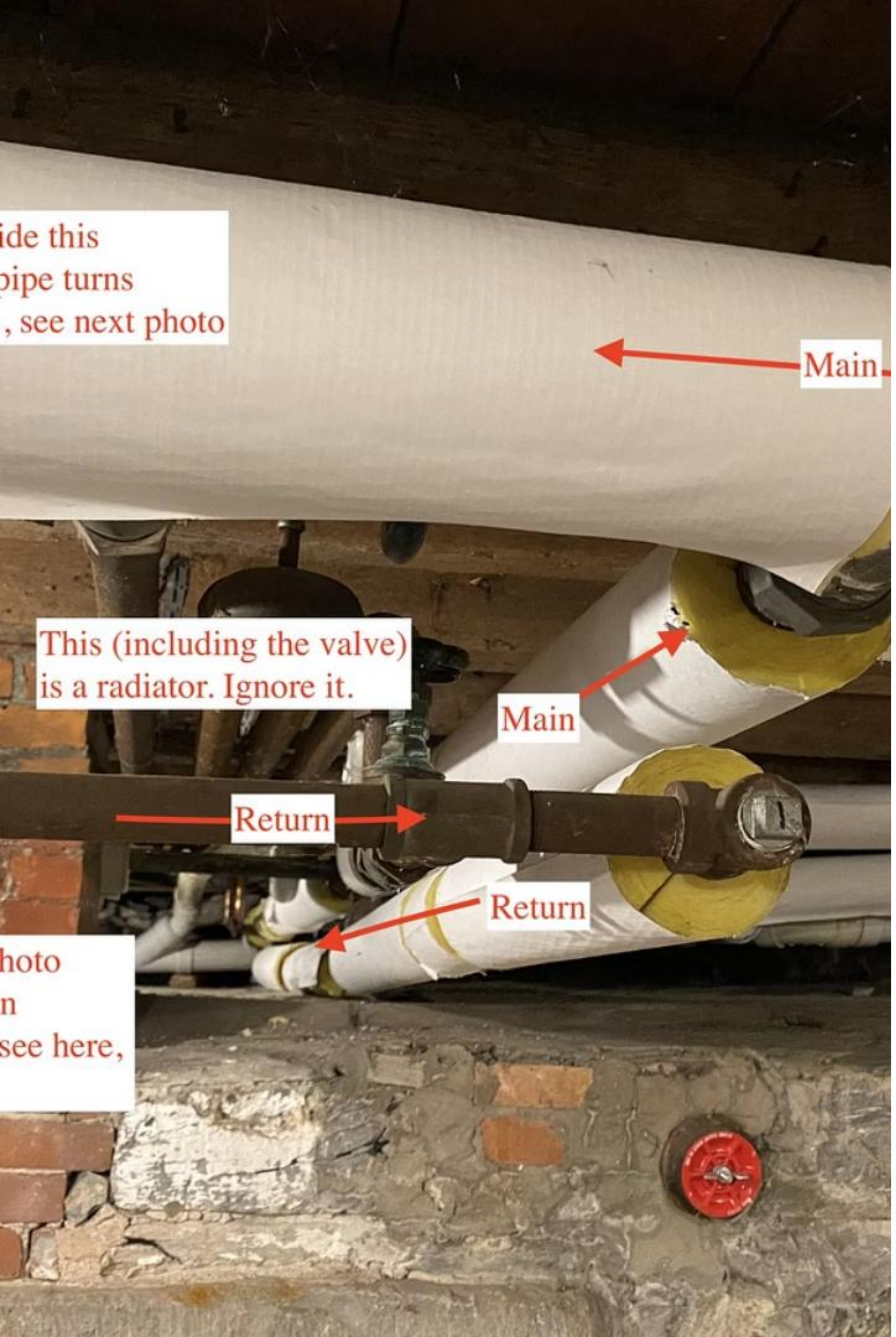
On your way out, turn off service riser valve or propane cylinder/tank shutoff valve. Do not return to the building with a wrench to turn off the main shutoff valve. Several deaths in the industry have occurred from such actions.

Call for help from a safe distance

Call for help using a telephone located at a safe distance from the area of the leak. Provide the property address, actions taken, information on the suspected cause, types of crew and equipment required, and any other backup personnel required.

Do not return to the building

Keep everyone, after evacuation, at a safe distance from the hazard area. Following building evacuation, stay clear and keep others at a safe distance. Remember that buildings are replaceable, lives aren't.



Step 5: Make Safe When Reading is Below LEL

Remain calm

The guidelines for making safe when the reading is below LEL are less drastic than for when there is imminent danger.

Ventilate the area

Operate exhaust fans, opening windows and doors, and forced air ventilation, if available. Fresh air ventilation will keep concentrations low.

For basement gas concentration

If gas is concentrating in a basement with a below LEL reading, open windows on each end of the basement. Mount a portable cooling fan in one window to blow air out. Make-up air will exhaust through the opposite window, creating a cross-draft.

Step 6: Cut Off Ignition Sources

When gas concentrations are below the LEL, you can safely cut off potential ignition sources by:

- Opening the master breaker at the electrical panel
- Turning off valves on lines supplying the various gas appliances

Only cut off ignition sources when gas concentrations are confirmed to be below the LEL. This includes electrical panels and gas supply valves.

Step 7: Determine Source of Leak

Note that odorants are not completely effective as a warning agent in all cases. You can properly odorized propane at a concentration of 1/5th of its LEL and properly odorized natural gas with the average nose at a concentration of approximately 500 ppm.

An older style combustible gas indicator, operating on the 0–100 LEL (0.5%) range, can detect concentrations of natural gas down to 1,000 ppm. In other words, the average nose may be twice as sensitive as the standard catalytic combustion scale on a combustible gas indicator. The nose and CGI together can help determine the source of a gas leak.

Determining Leak Source by Smell and Reading

Faint smell and strong reading

Likely an outside, below-ground leak that has infiltrated the building

- Gas diffuses through soil seeking a venting location
- Often finds its way into conduit systems, sewer lines, manholes, vaults or pits, as well as building foundations
- Odorant compounds (mercaptans) tend to adhere to soil particles; soil acts as a filter for the odour molecules
- By the time gas infiltrates buildings, the odour may be entirely absent

Strong smell

Likely a leak inside the building

- If there is a noticeable smell of fuel and the reading is below the LEL, you are safe to continue to monitor the free atmosphere in the basement
- Check all potential leak points including conduit entry points, gas service entry, below-grade cracks in the basement walls, etc.

Actions for Outside, Below-Ground Leaks

Call the gas utility (supplier)

You should call the gas utility (supplier) to have the area tested. Keep in mind that time is of the essence.

Assess the situation outside

At this point you should go outside to "assess the situation on the street". You may perceive evidence of recent construction or other activity that could have damaged the pipeline or underground propane service line.

Shut off propane supply if applicable

Shut off the propane cylinder/tank service valve if the gas supply to the premises is propane. Take all precautions.

Actions for Inside Leaks

Check potential leak points

- All conduit entry points
- The gas service entry
- Below-grade cracks in the basement walls
- Floor drains and sump pump holes
- Ceiling atmosphere
- The piping
- Low-lying areas
- Fittings and manifolds of appliances
- Other points where gas could leak or collect

Additional tests

- Take dial-gauge/manometer test reading
- Do soap test
- Shut off all appliances at service valves and listen for the sound of gas passing

Investigating Incomplete Combustion

If, when responding to an odour call, you determine that the odour is not a natural gas or propane leak, you should check for carbon monoxide. Carbon monoxide is a colourless, toxic gas with a specific gravity of 0.98.

Whilst carbon monoxide is odourless by itself, the creation of aldehydes and sulphur dioxide, which are irritating and toxic substances may cause a pungent odour that sometimes accompanies CO.

Technicians/Fitters should test for carbon monoxide as they enter a structure. Any increase over outside ambient levels should be investigated to determine the source.

Always test for carbon monoxide when entering a structure, especially when responding to odor complaints that aren't clearly gas leaks.

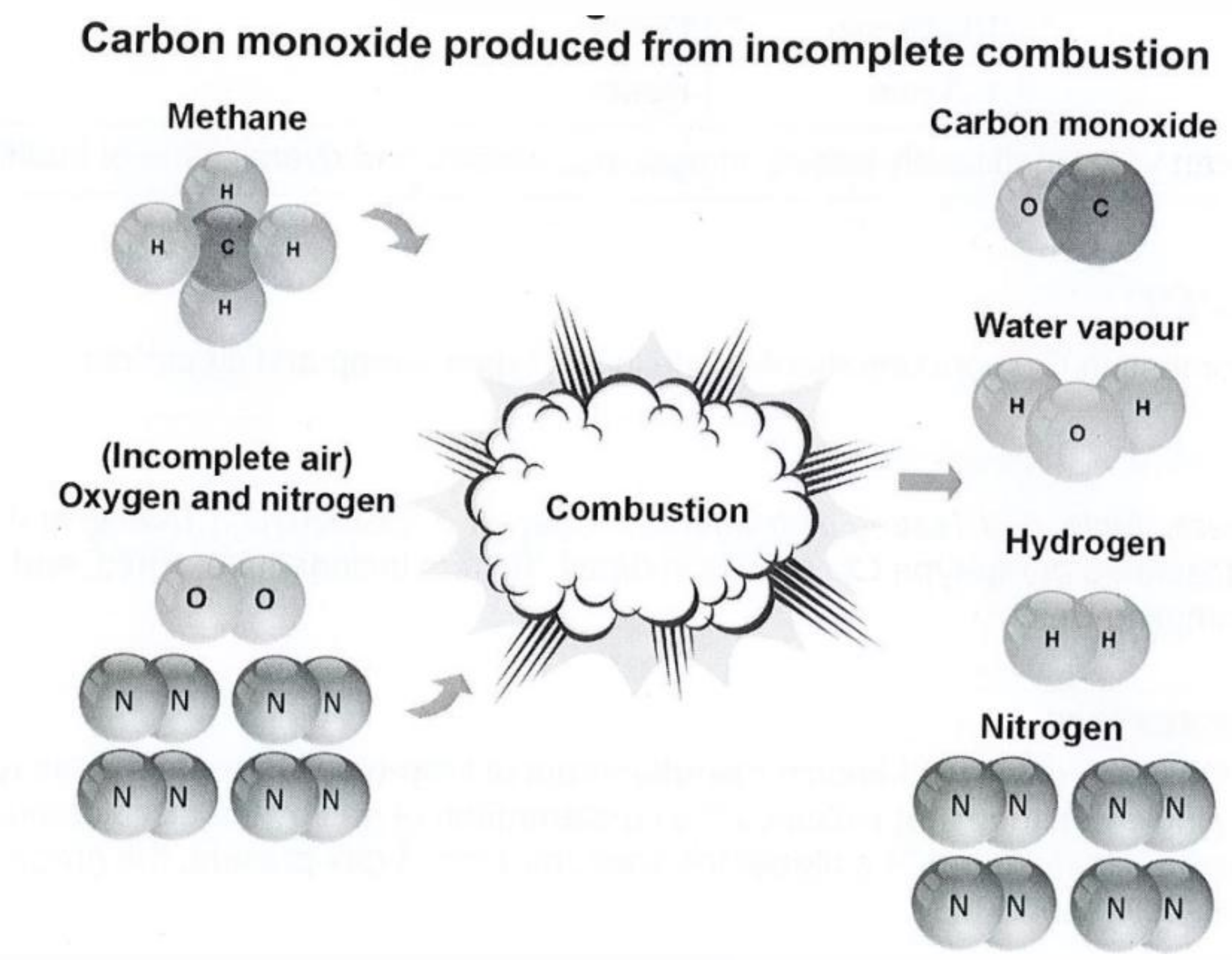
Carbon Monoxide: A Direct and Cumulative Poison

Carbon monoxide is a product of incomplete combustion. It is a direct and cumulative poison. Carbon monoxide bonds with blood hemoglobin to form carboxyhemoglobin.

Carbon monoxide bonds with hemoglobin 200 times easier than oxygen. CO replaces oxygen in the blood until it completely overcomes the body.

Death from CO occurs rapidly at high concentrations. The victim inhaling the toxic concentration of the gas becomes helpless before realizing that danger exists.

Chronic exposure to low levels of carbon monoxide can compound preexisting health conditions and is often misdiagnosed due to common symptoms like headache, nausea, vomiting, head stuffiness, and fatigue.

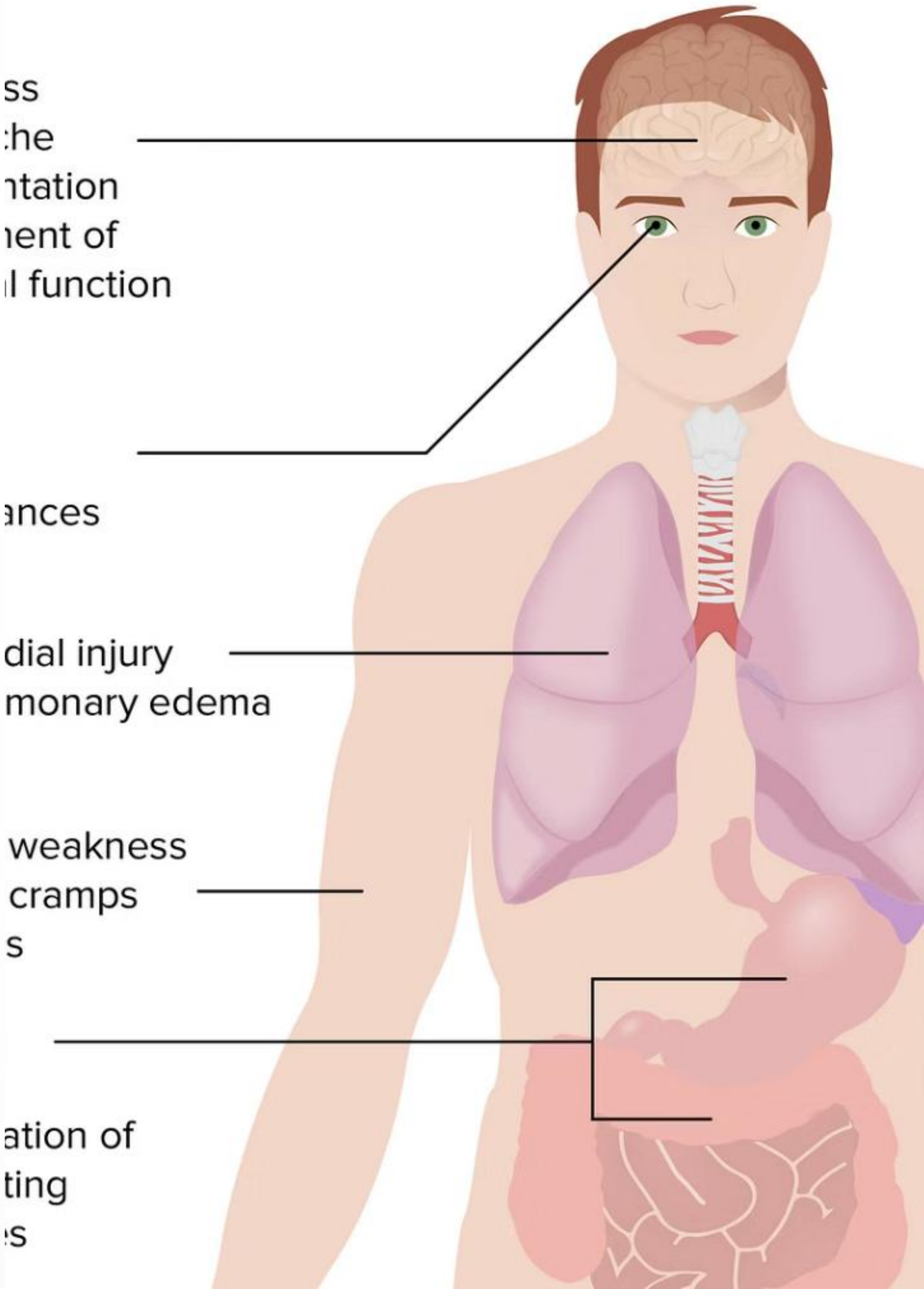


Incomplete combustion produces carbon monoxide, which can be deadly even in small amounts.

Toxic Symptoms of CO Exposure

Concentration of CO in air	Inhalation time	Toxic symptoms developed*
200 ppm	2-3 h	Slight headache, tiredness, dizziness, and nausea
400 ppm	1-2 h	Frontal headache
400 ppm	3+ h	Life-threatening
800 ppm	45 min	Dizziness, nausea, and convulsions
800 ppm	2 h	Unconsciousness
800 ppm	2-3 h	Death
1,600 ppm	20 min	Headache, dizziness, and nausea
1,600 ppm	60 min	Death

*Symptoms can vary significantly based on age, sex, weight, and overall state of health.



CO Testers: Pump-Type

Tube-type testers

Draeger and Gastec are two well-known manufacturers of tube-type CO testers. This type of tester uses a single-use tube that indicates the concentration of gas by the discoloration of a dry chemical contained in the tube. The higher the concentration of gas present, the greater the extent of the discoloration.

Liquid-type testers

Another common CO tester is the liquid-type Unit. This type of tester is partially filled with a liquid that absorbs CO. The higher the concentration of CO present, the greater the expansion of the liquid. The amount of expansion is measured on a scale on the side of the tube. Unlike the tube tester, the liquid tester can help take several samples without having to change the chemicals.

Continuous sampling testers

These testers take a continuous sample of the gas through a sampling tube inserted into the area being tested. Readings are displayed on a dial indicator. Some Units provide a printout of the readings for future reference.

CO Testers: Electronic Type

Electronic CO testers, like the Bacharach Monoxor® III Unit, are light-weight, portable, hand-held solid-state instruments with continuous readout digital displays.

They can measure and display CO levels from 0 to 2,000 ppm.

To take a reading, the operator inserts the attached sensor probe into the flue or airspace being sampled and reads the indicated value on the tester display.

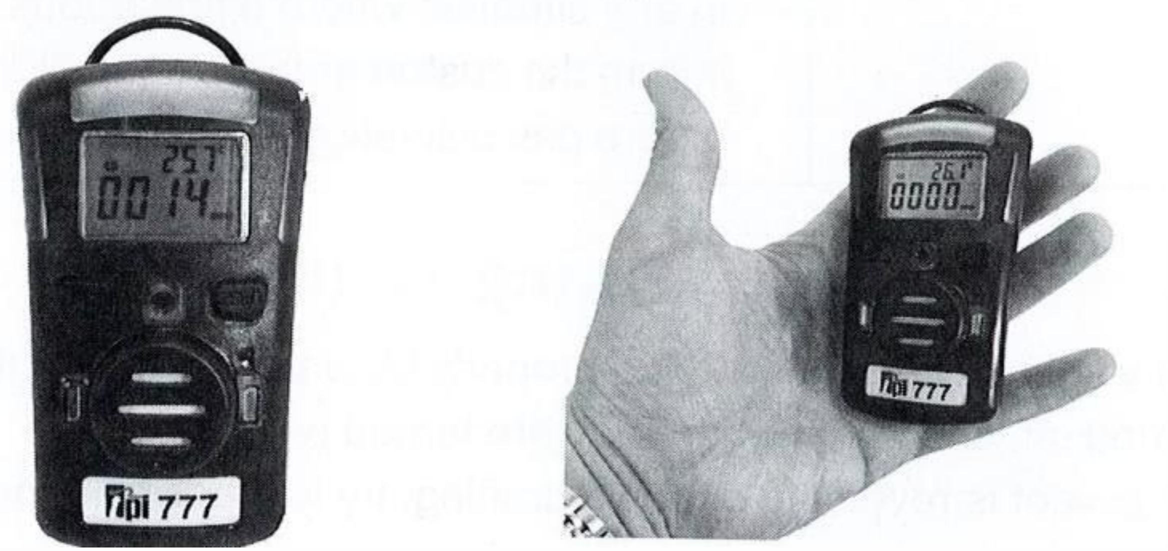


Figure 3-6
Continuous sampling CO Analyzer
Image courtesy of TPI

Electronic CO testers provide quick, accurate readings and are easier to use than traditional pump-type testers.

Investigating Incomplete Combustion: Step 1

Check products of combustion

Check the products of combustion on all vented appliances (on an air-free basis). You are looking for high levels of carbon monoxide (CO).

If CO levels are high

If a vented appliance produces more than 400 ppm of CO air-free and cannot be adjusted to produce less, disconnect and red-tag the appliance. Under normal operation, an appliance should produce less than 50 ppm of CO (air-free).

In any situation where a hazardous condition exists, inform the customer that the appliance needs repair before gas activation is possible. Vented appliances should never produce more than 400 ppm of CO on an air-free basis.

If products of combustion test are normal

Check the house atmosphere for CO. If the inside atmosphere CO level exceeds 35 ppm, ventilate the building and shut off the appliances.

In any situation where a hazardous condition exists, inform the customer that the appliance needs repair before gas activation is possible.

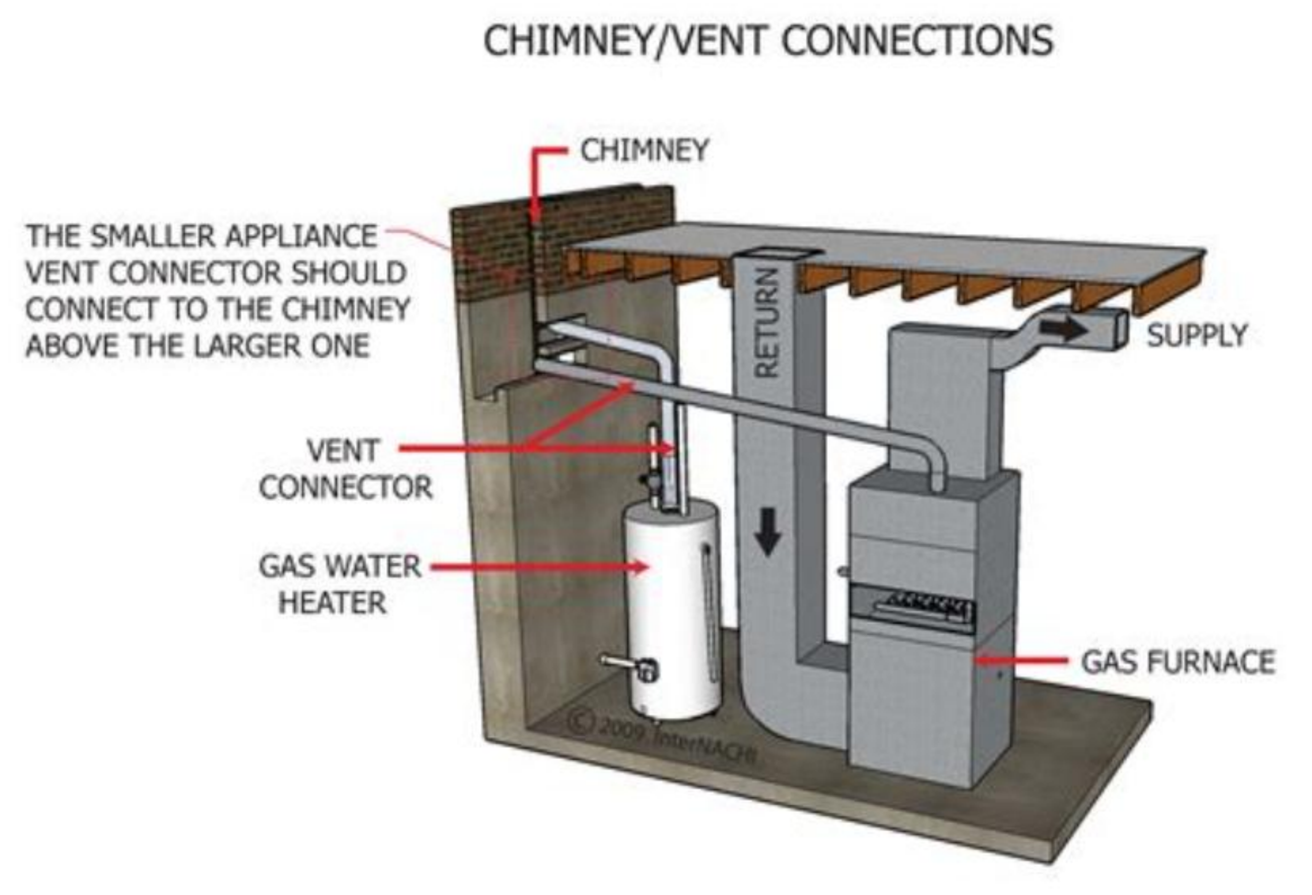
Investigating Incomplete Combustion: Step 2

Check appliance venting system

Check that the venting system is working properly by watching the venting action with the appliances turned off, and again when they are turned on.

If the chimney or vent is reversing or down drafting, try to determine the cause by checking for the following:

- An active fireplace or open fireplace damper
- Exhaust fans
- Adequate combustion and ventilation air
- Proper chimney or vent height
- Proper termination location
- Proper rain cap on Type B vent



Proper venting is critical to prevent carbon monoxide buildup. Check for proper draft and ensure all components are correctly installed.

Investigating Incomplete Combustion: Step 3

Check other fuel-burning appliances

Check other fuel-burning appliances such as:

- Gas ovens
- Gas ranges
- Gas fireplaces
- Gas water heaters
- Wood stoves
- Wood furnaces
- Oil-fired vented appliances

Check venting system

Check the sizing of the venting system to ensure it is appropriate for the number and types of appliances.

Check the condition of the venting system and clean out any obvious debris in the chimney cleanout.

Investigating Incomplete Combustion: Step 4

Check furnace heat exchanger

Check the furnace heat exchanger for cracks. If you find cracks, inform the customer that the heat exchanger needs replacement or that a new furnace is required.

Check secondary heat exchanger

Check the furnace for a secondary heat exchanger. If there is one installed, examine it to determine whether it is an acceptable type and whether it is in good condition.

Investigating Incomplete Combustion: Step 5

Clock the gas meter

Clock the gas meter and determine the input for each vented residential gas appliance.

Check commercial equipment

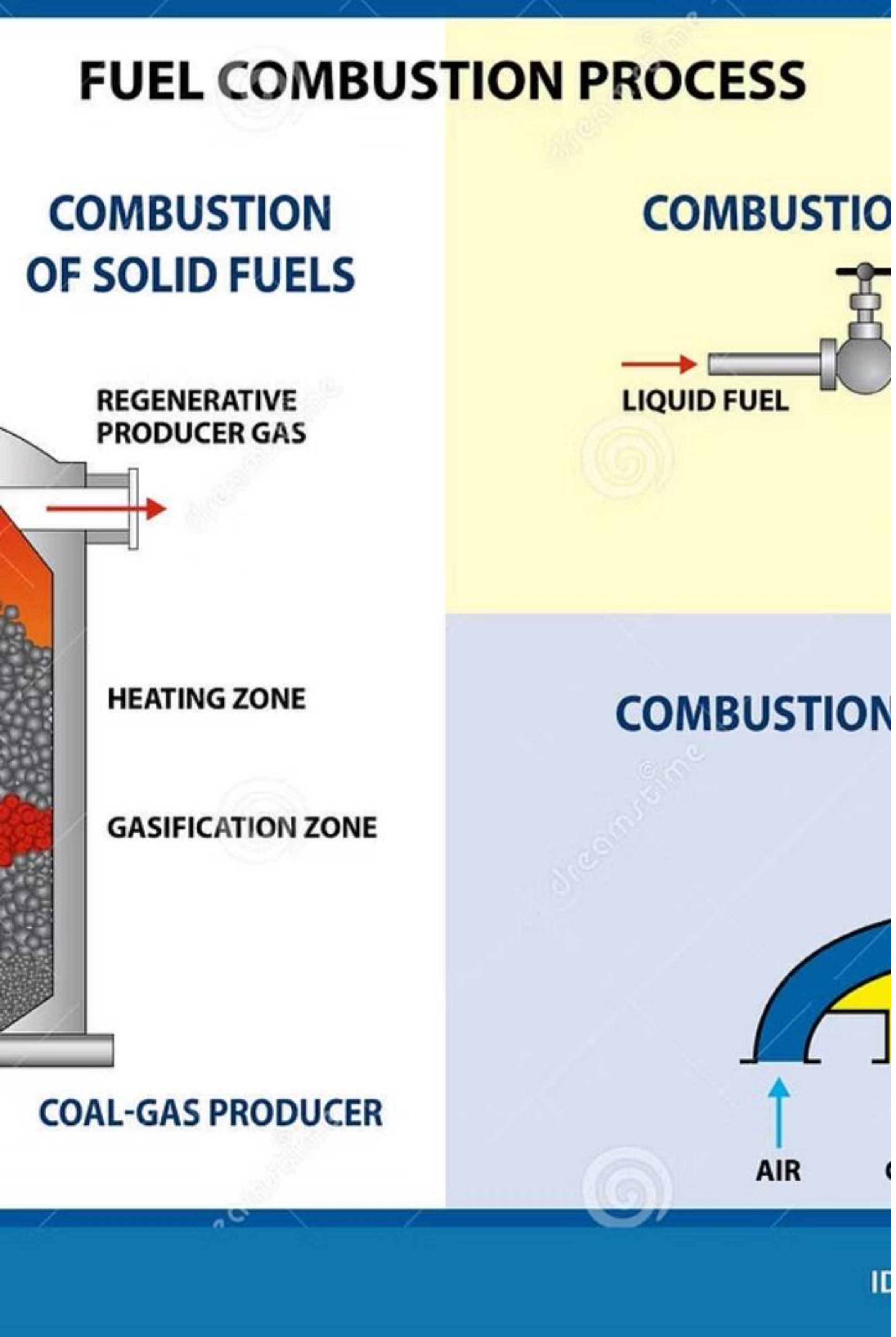
Check all industrial and commercial equipment, if installed.

Check for other causes of odours

Check for other causes of odours, when unable to find, such as paint and solvent fumes, kerosene heaters, and auto engines operating.

Air Categories for Combustion

Definition	Category of Air
Supplied to ensure that complete combustion has occurred	Excess air
Supplied from around the flames	Secondary air
Supplied to the combustion chamber in excess of the air required for perfect combustion	Excess air
Supplied to cool the hot vent gases	Dilution air
Provides a source of air to the draft control device	Dilution air
Combustion, excess, and dilution air requirements added together	Total air
Supplied to mix with fuel gas before ignition	Primary air



Combustion Temperature and Air Requirements

1300°F

Combustion Temperature

The combustion process must maintain a temperature of approximately 700°C (1300°F) for natural gas

100 ft^3

Air Requirement

100,000 Btu/h requires 100 ft^3 of combustion air

2550 ft^3

Large Appliance Requirement

255,000 Btu/h requires 2,550 ft^3 combustion air

Effects of Corrosive Vapours

Experience has shown that contaminants in the combustion air almost always causes corrosion of gas-fired equipment.

The most common corrosive element is a member of the family of substances known as chlorinated hydrocarbons. These materials are solvents, or refrigerants. When heated, the molecules of these compounds break down to form a variety of substances, some of which are very corrosive.

Corrosive vapors can severely damage gas equipment, leading to premature failure and potentially dangerous conditions.

Common Corrosive Substances

Cleaning Products

- Materials used for degreasing metal parts
- Materials used for cleaning jewelry, electronic components, etc.
- Solvents for removing grease, wax, or printing ink
- Paint and varnish strippers
- Dry cleaning solvents
- Bleaches

Adhesives

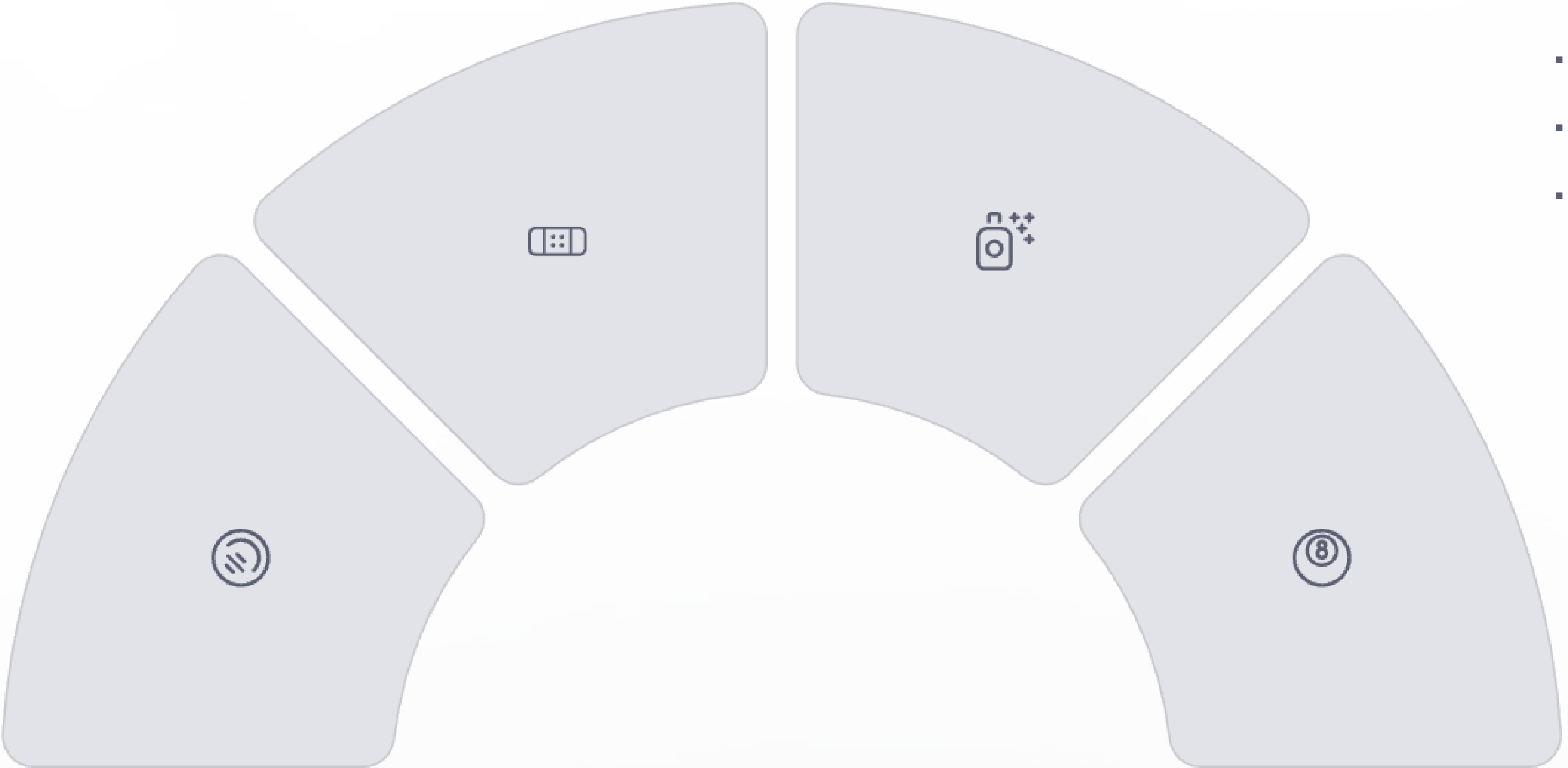
- Glues of many types, except those with a water base

Aerosols

- Propellants used in aerosol sprays

Other Substances

- Freon-type refrigerants
- Swimming pool chlorine
- Kitty litter



Identifying Corrosive Substances

When used in a solvent form, corrosive materials are often clear, colourless, watery liquids. They are normally nonflammable and relatively nontoxic. When mixed with glues, they are difficult or impossible to identify without testing.

Solid substances do not usually cause corrosion.

For positive identification, you need to know the chemical constituents of the suspect materials. The easiest way is to read them off the container label. If the chemical name of a solvent-type substance contains the letters "chlor" or "fluor", you can be almost certain you have found the problem material.

Known corrosion-causing substances:

- Chlordane
- Refrigerants
- Methylene chloride
- Perchloride
- Trichlorophenol
- Trichlorfon

Chemistry of Corrosion

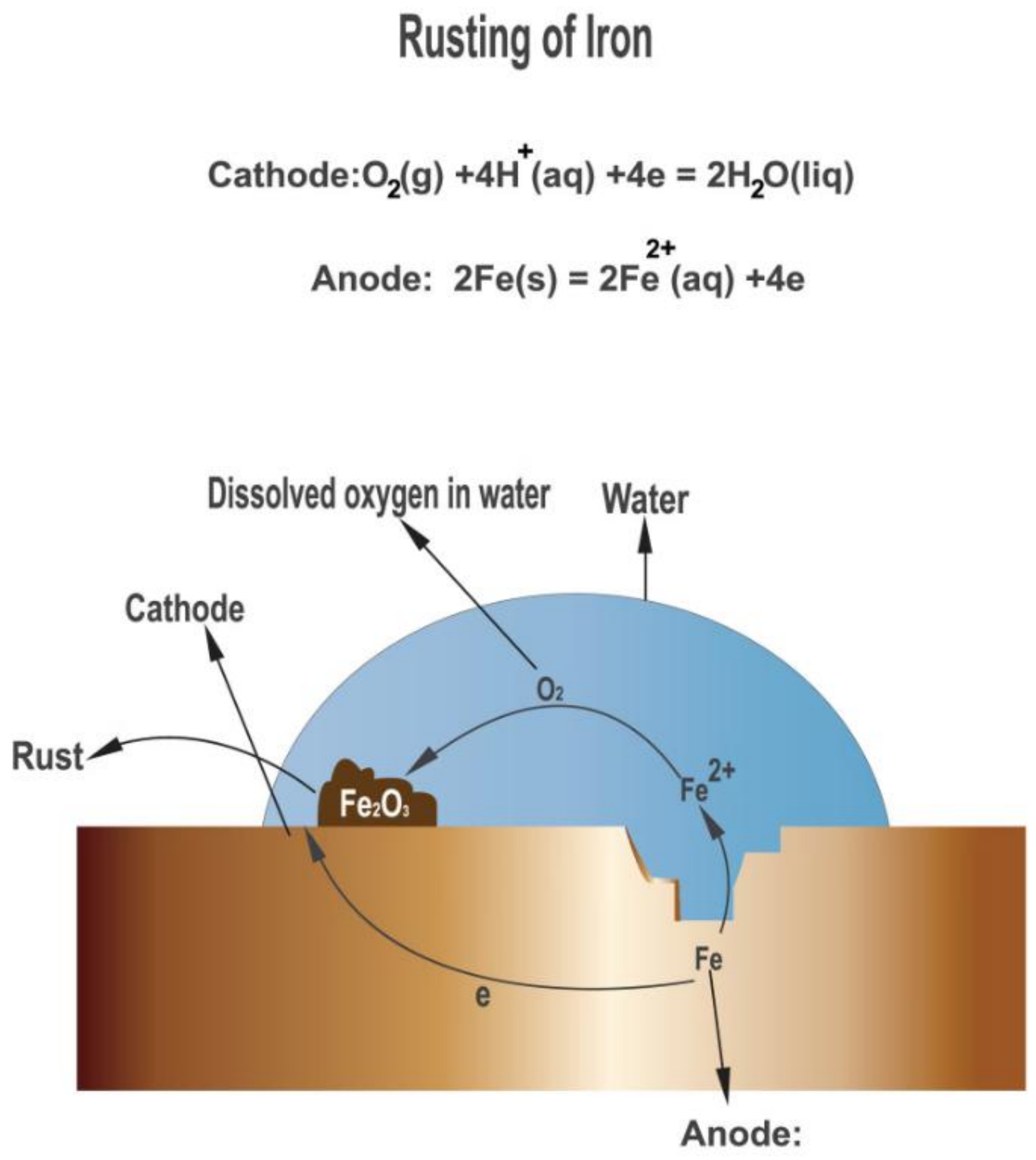
The equation below shows, in a simplified manner, one of the possible reactions that can occur when a chlorinated hydrocarbon (methylene chloride, in this example) is heated in air:

$CH_2Cl_2 + O_2 = CO_2 + 2HCl$

methylene chloride + oxygen = carbon dioxide + hydrogen chloride

In this reaction, the methylene chloride combines with oxygen to produce the gases carbon dioxide and hydrogen chloride.

Hydrogen chloride gas is very soluble in water. In the presence of the slightest trace of water, it forms hydrochloric acid. This acid can attack various appliances and heating system components.



When chlorinated hydrocarbons are heated during combustion, they can form

Appliances Vulnerable to Corrosion

Furnace Heat Exchangers

At the beginning and end of each burner cycle, the heat exchanger is relatively cool, allowing water and acid to form.

Water Heaters

During high draws, the heat exchanger temperatures are quite low. More condensation occurs during this time, leading to higher corrosion rates.

Unit Heaters

These are also vulnerable to corrosion from condensation.

Boilers

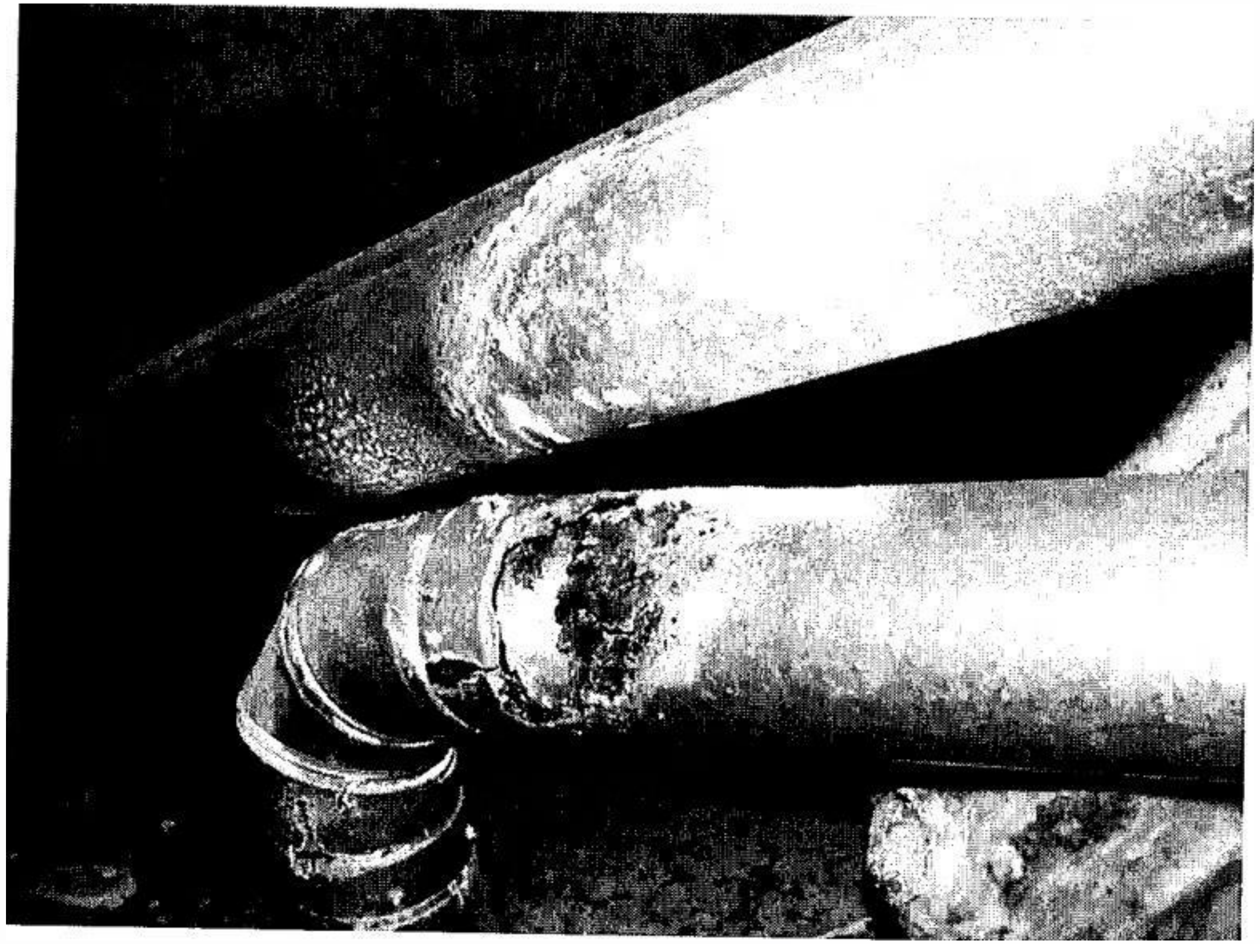
Often least affected because inner surfaces are nearly always hot enough to prevent condensation. However, boilers with finned tubes and swimming pool heaters frequently have condensation problems.

Spotting Corrosion

In appearance, the corrosion looks like ordinary rust—it can be a fine red powder or large rusty scales or flakes.

One of the additional characteristics of this type of corrosion is the presence of whitish, powdery streaks that run down and dry on galvanized vents (aluminum vents are less affected).

In cases of fresh corrosion, the streaks will be wet and appear oily. The inner surfaces show a slight amount of white powder. They tend to last fairly well, but get thinner and thinner with time.



Corroded venting due to leaking

Corrective Measures for Corrosion

Installation Precaution

Do not install an appliance in a room that has an atmosphere containing corrosive vapours, such as that found in a dry-cleaning establishment.

Finding Alternatives

When you find corrosion to be causing the deterioration of gas-burning equipment, you must take corrective measures before replacing the equipment. When possible, encourage the customer to find a replacement for the corrosive substance.

Industrial Applications

In industrial applications, it is often impossible to cure the problem completely. The chlorinated hydrocarbon causing the corrosion is often crucial to plant operation, with no acceptable replacement substance.

Reducing Corrosion Problems

Ventilated Storage

Store, transfer, and use the solvent in a closed, fan-ventilated room. No gas-fired equipment should be in the room. Doors leading to this room should be well-sealed and closed at all times.

Minimize Open Containers

Try to avoid open containers of solvent. Often, you can find many small containers of solvent around the plant or in the home that are not really needed.

Consider Direct Vent Systems

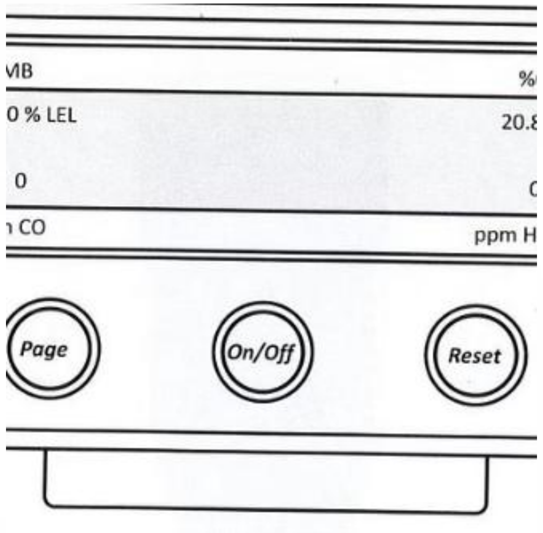
Direct vent and roof-mounted heaters are best, as long as all combustion air comes from outdoors. Be aware that vents or exhaust fans that dump contaminated air at roof level should not be near the intake of a roof unit or direct vent appliance.

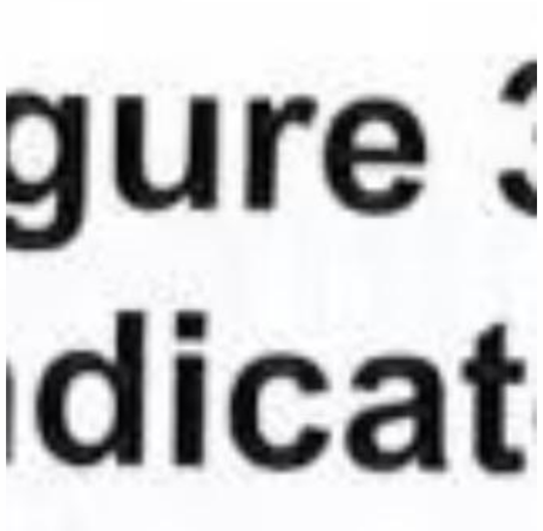
Consider Hot Water Heating

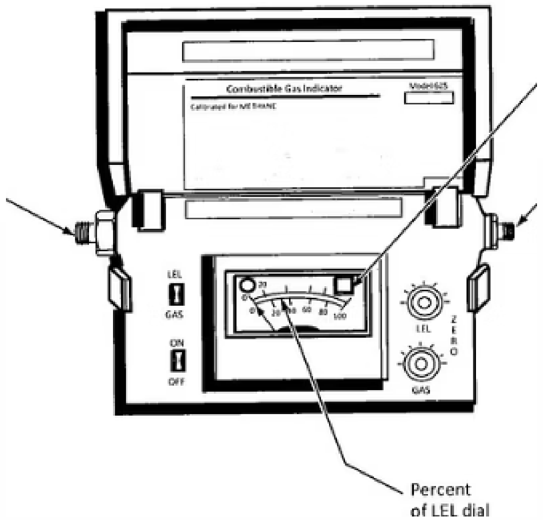
Hot water or steam heating is the next best choice. Place a boiler or water heater in an enclosed area away from the solvent. To avoid condensation problems, pay careful attention to finned-tube boiler installations.

Air Categories Review

Combustible Gas Indicator Selection







When selecting a combustible gas indicator, ensure it's calibrated for the specific gas you're testing for. Each manufacturer makes many different models, so be sure you have the correct instrument for the job at hand. An instrument calibrated for a known gas at the manufacturer's plant (a standard calibration) is usually most suitable.

Gas Leak Response Procedure Summary

Prepare

Gather equipment and prepare CGI

Approach

Knock, don't use doorbell

Test

Take readings at appropriate locations

Respond

Take action based on readings

Investigate

Determine and address the source

Carbon Monoxide Testing Equipment

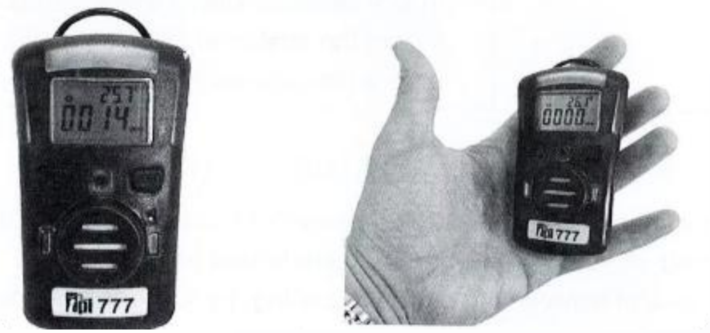
Tube-Type Testers

Uses a single-use tube that indicates the concentration of gas by the discoloration of a dry chemical contained in the tube. The higher the concentration of gas present, the greater the extent of the discoloration.

Liquid-Type Testers

Partially filled with a liquid that absorbs CO. The higher the concentration of CO present, the greater the expansion of the liquid. Can take several samples without changing chemicals.

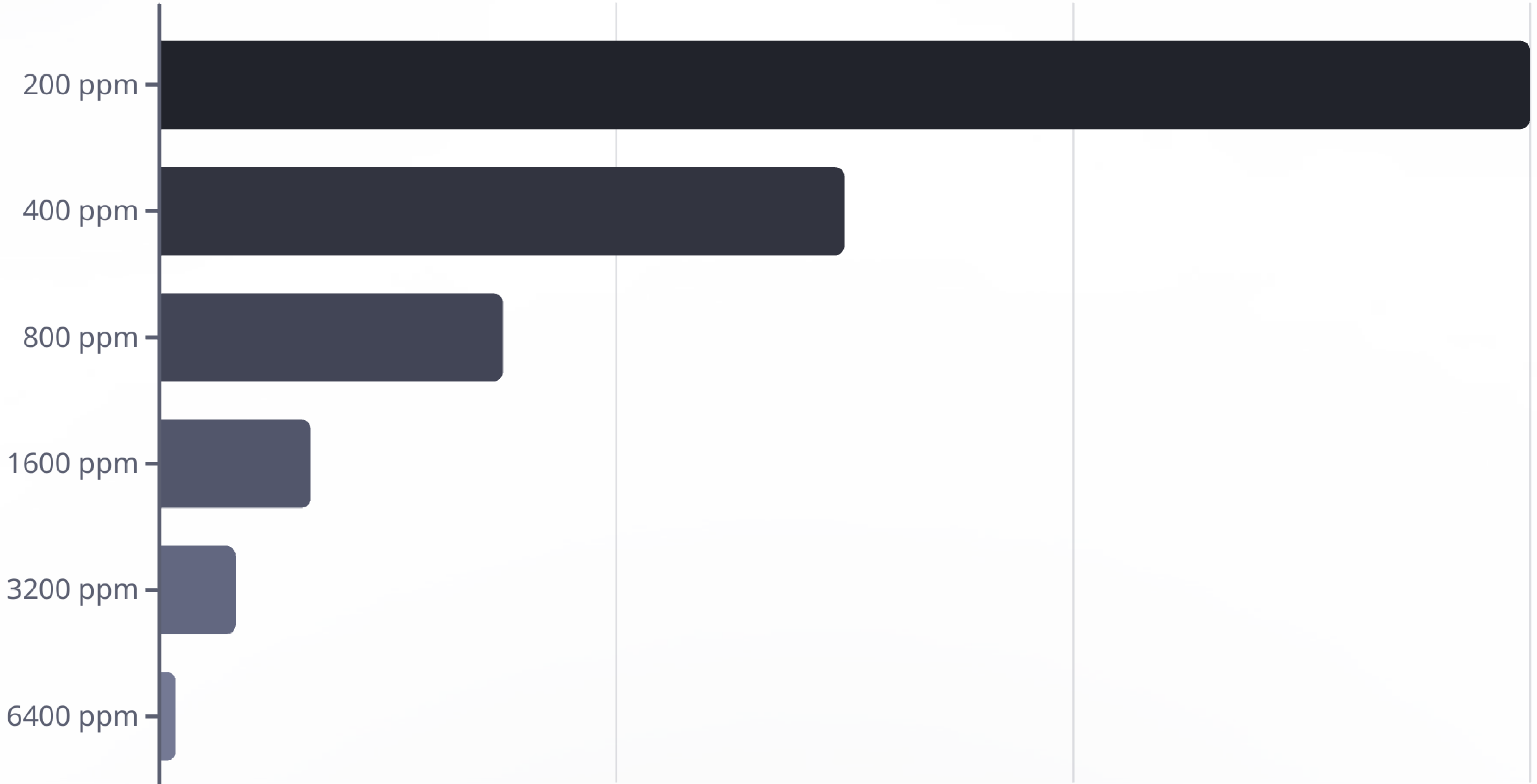
Figure 3-6
Continuous sampling CO Analyzer
Image courtesy of TPI



Electronic CO Testers

Light-weight, portable, hand-held solid-state instruments with continuous readout digital displays. Can measure and display CO levels from 0 to 2,000 ppm.

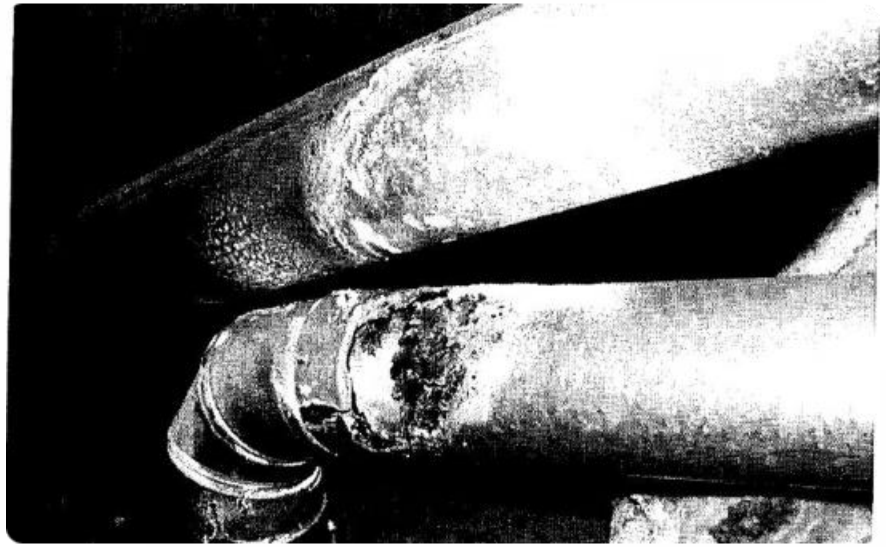
Carbon Monoxide Exposure Risks



Corrosive Substances Identification

For positive identification of corrosive substances, check the chemical constituents on the container label. If the chemical name contains the letters "chlor" or "fluor", it's likely a corrosion-causing substance. Examples include chlordane, methylene chloride, perchloride, trichlorophenol, and trichlorfon.

Corrosion Effects on Gas Equipment



Corroded Venting

Corrosion appears as ordinary rust—fine red powder or large rusty scales or flakes. Whitish, powdery streaks often run down and dry on galvanized vents.

Heat Exchanger Damage

Heat exchangers are particularly vulnerable at the beginning and end of each burner cycle when temperatures are lower and condensation can occur.

Boiler Tube Deterioration

Finned tubes in boilers and swimming pool heaters can suffer from condensation problems, leading to corrosion and eventual failure.

Combustion Process Requirements

Temperature

The combustion process must maintain a temperature of approximately 700°C (1300°F) for natural gas

Oxygen

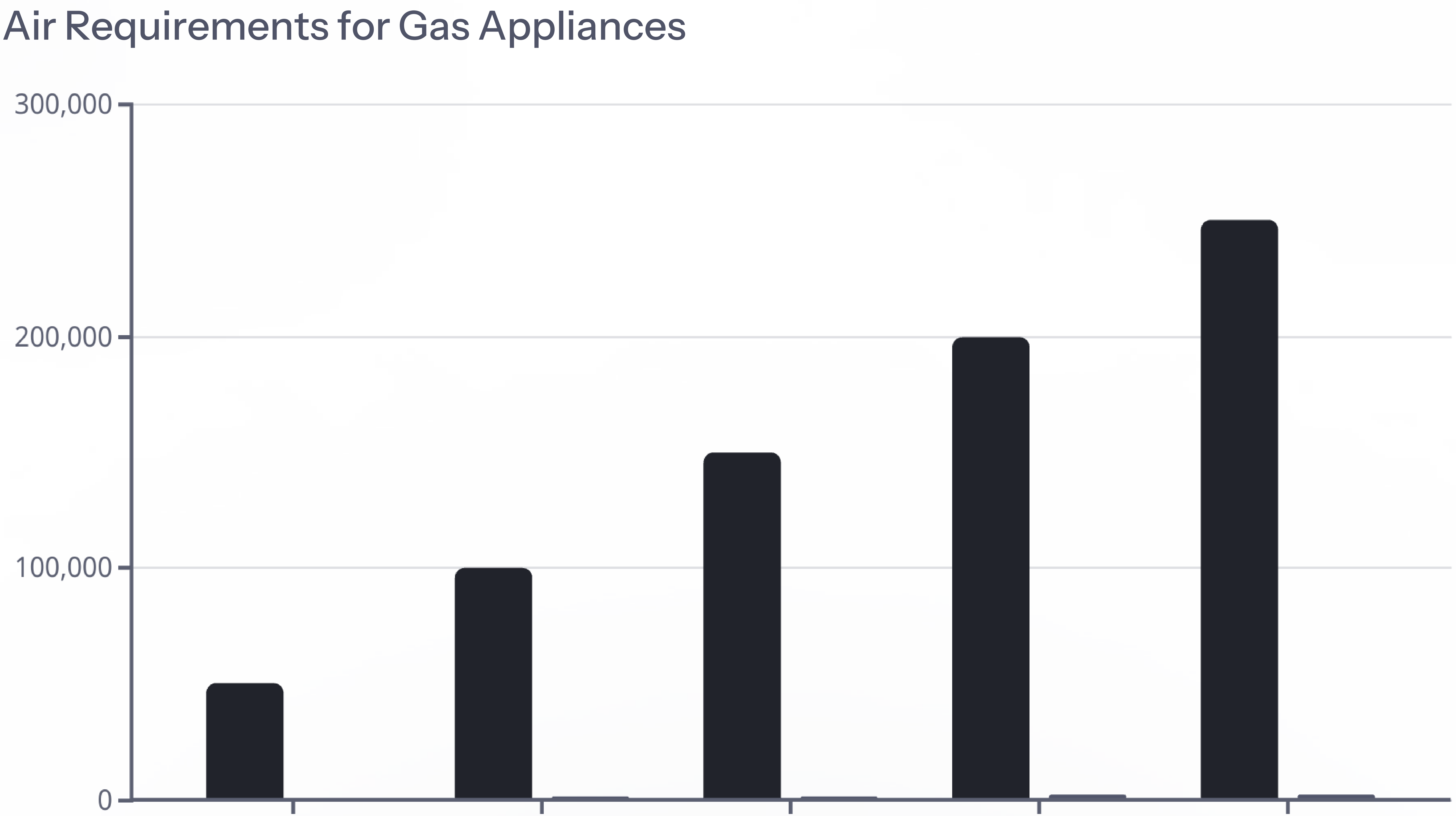
Sufficient oxygen must be available for complete combustion

Time

Adequate time for complete combustion reaction

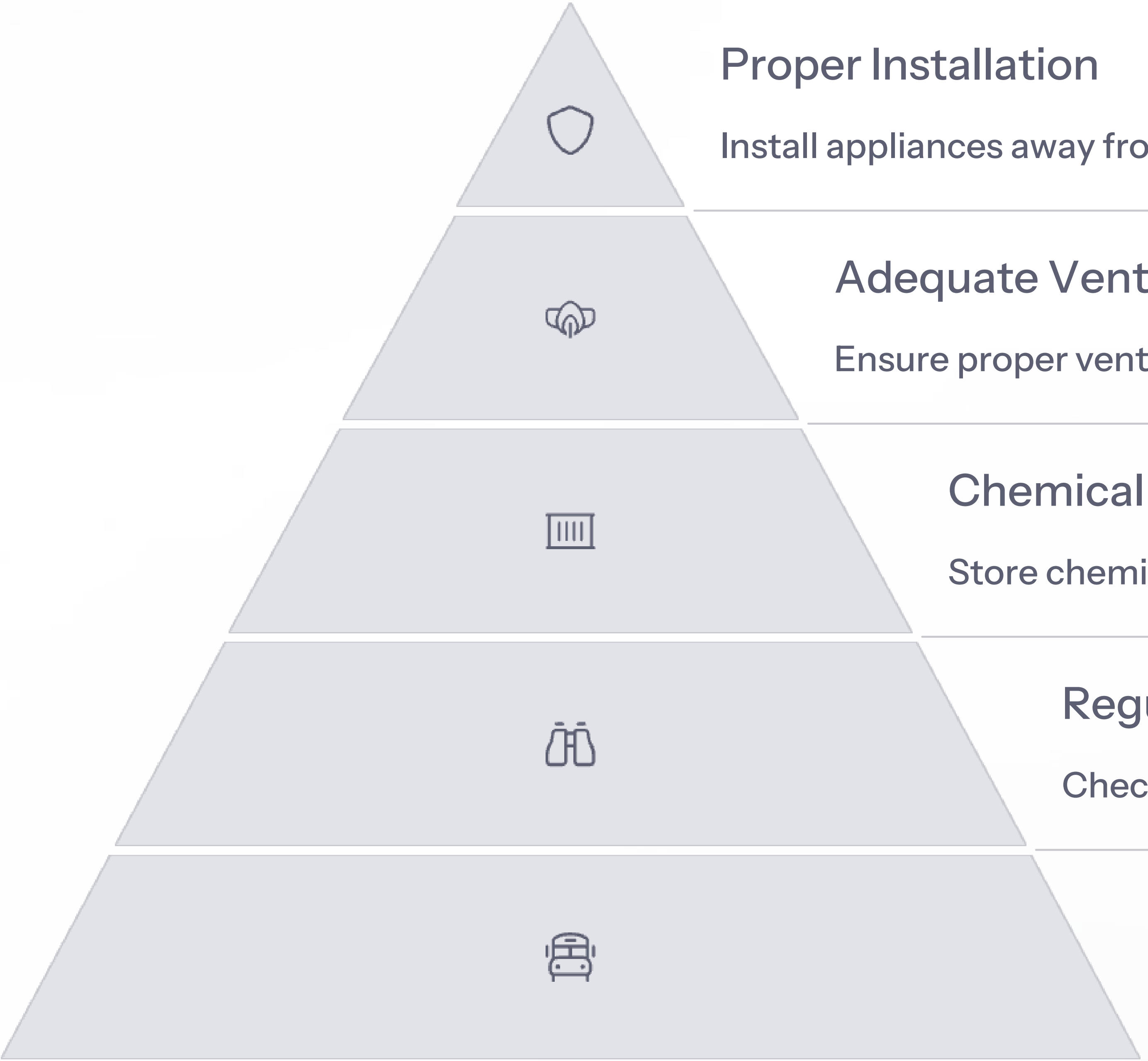
Fuel

Proper fuel-to-air ratio is essential



Air Requirements for Gas Appliances
300,000
200,000
100,000
0

Preventive Measures for Corrosion



Proper Installation

Install appliances away from corrosive environments

Adequate Ventilation

Ensure proper ventilation in areas with potential corrosive substances

Chemical Storage

Store chemicals properly in sealed containers away from appliances

Regular Inspection

Check for early signs of corrosion during maintenance

Customer Education

Inform customers about corrosion risks and prevention

Gas Leak Investigation Equipment

Combustible Gas Indicator

Essential for detecting gas-air mixtures and determining explosive levels. Available in solid-state and filament types, with solid-state being more sensitive and commonly used.

Leak Detection Soap Solution

Used to visually identify the exact location of gas leaks by forming bubbles when applied to fittings, connections, and other potential leak points.

Pressure Gauge/Manometer

Used to measure gas pressure in lines and at appliances to help identify pressure-related issues that might contribute to leaks or improper operation.

Natural Gas vs. Propane Leak Detection

Natural Gas

Specific gravity: approximately 0.60 (lighter than air)

Leak detection location: Test in the basement stairwell, immediately after entering the building, near the top of the door

Behavior: Tends to rise or follow any path of least resistance

LEL: 4%

Detection: The average nose can detect properly odorized natural gas at approximately 500 ppm

Propane

Specific gravity: greater than air (heavier)

Leak detection location: Begin testing at floor level

Behavior: Tends to collect at lower levels

LEL: 2.4%

Detection: Can be properly odorized at a concentration of 1/5th of its LEL

Incomplete Combustion Investigation Process

Test for CO

Check for carbon monoxide upon entering the structure

Check Vented Appliances

Test products of combustion on all vented appliances

Inspect Venting System

Check venting system operation and condition

Examine Heat Exchanger

Check for cracks or damage

Verify Appliance Input

Clock the gas meter to determine proper input

Check Other Sources

Investigate other potential causes of odors

Chemistry of Corrosion in Gas Equipment

Chemical Reaction

$CH_2Cl_2 + O_2 = CO_2 + 2HCl$

When methylene chloride (a common chlorinated hydrocarbon) is heated in air, it combines with oxygen to produce carbon dioxide and hydrogen chloride gas.

Hydrogen chloride gas is very soluble in water. In the presence of the slightest trace of water, it forms hydrochloric acid, which is extremely corrosive to most metals.

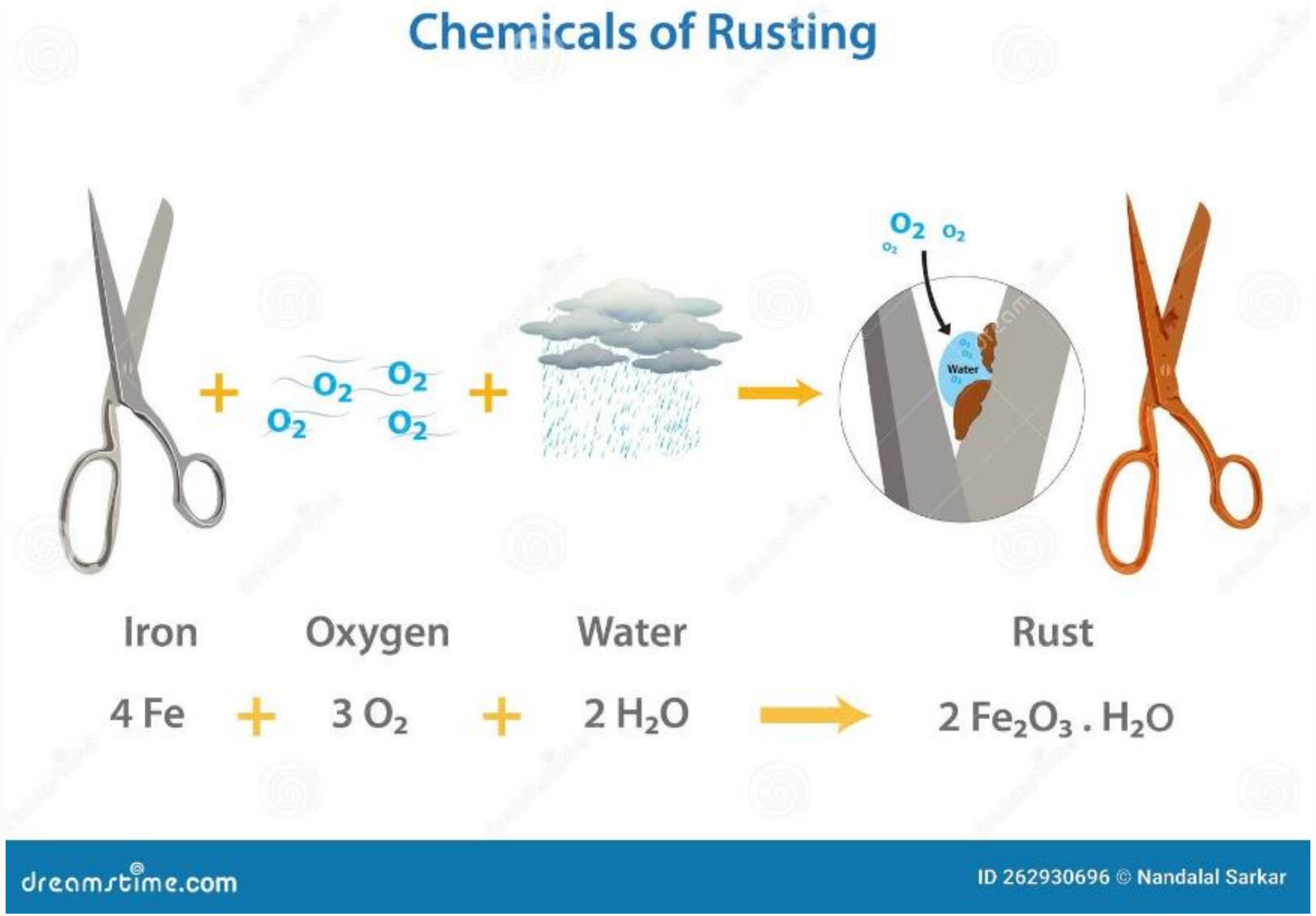
This reaction occurs during the combustion process when chlorinated hydrocarbons are present in the combustion air.

Condensation Points

At the beginning and end of each burner cycle, the heat exchanger is relatively cool. Water in the combustion products can condense in small amounts during these two brief times.

The hydrogen chloride dissolves in this water to form hydrochloric acid, which attacks the metal components.

In water heaters during high draws, the heat exchanger temperatures are quite low, leading to more condensation and potentially higher corrosion rates.



Summary: Gas Hazards and Safety Procedures

Gas Detection

Use appropriate combustible gas indicators to detect gas leaks. Understand the differences between solid-state and filament-type indicators and their proper use.

Gas Leak Response

Follow proper procedures when responding to gas leak calls: prepare, knock (don't use doorbell), communicate safety instructions, take readings, and make safe based on readings.

Incomplete Combustion

Test for carbon monoxide when investigating odors that aren't gas leaks. Check vented appliances, venting systems, heat exchangers, and appliance input.

Corrosive Vapors

Understand how chlorinated hydrocarbons can cause corrosion in gas equipment. Take preventive measures by proper installation, ventilation, and chemical storage.