Fire Smoke and Buildings

Characteristics of Smoke

Smoke generated by fire has long been recognized as a potential threat to life. A fatality as a result of fire is often due to the effect of smoke rather than the effect of heat.

Two important features of smoke are:

toxic products of combustion and

reduction in visibility.

The two factors are generally related. Dense smoke is usually highly toxic and reduces visibility substantially.

The objectives of smoke control

The need to control smoke in a fire seems obvious and the BCA requires that occupants of buildings be safeguarded in a variety of ways from the effects of smoke and its potential to hinder their escape.

The objectives of smoke control should encompass:

- the maintenance of escape paths free of smoke
- control of the spread of smoke
- the reduction of smoke that may hinder the fire-fighter's role
- the reduction of smoke damage to other parts of a building affected by fire.

Smoke Developed Index

The smoke developed index relates to the optical density of smoke produced under the conditions of the standard test.

Doubling of the optical density of the smoke increases the smoke developed index. The higher the index, the greater the hazard is likely to be from smoke.

The thickness of the material can affect the smoke produced as can the mass to surface area ratio.

Spread of Flame Index

The spread of flame index is based on studies of actual rates of spread of flame on various wall-lining materials.

Where the walls of rooms with 2.75m ceiling height were lined with materials with high spread of flame indices, flames rapidly spread up the wall and, by igniting combustible gases that had accumulated below the ceiling, rapidly involved the whole room in fire.

An index of 10 indicates that the material could be expected to cause flames to reach the ceiling of such a room within 10s of ignition; an index of zero means that the materials will not cause flames to reach the ceiling.

TABLE 1 RESULTS OF EARLY FIRE HAZARD TESTS

(FROM AS 1530.3-1999)

Material Tested	Bottom of Range I	S	H	Sm	Top of Range I	S	H	Sm
Glass fibre insulation	0	0	0	0	0	0	0	3
Mineral fibre insulation batts	0	0	0	0	0	0	0	3
Asbestos cellulose board	0	0	0	0	0	0	0	0
Glass reinforced plaster	0	0	0	0	0	0	0	0
Hardboard	14	7	6	3	14	7	9	5
Wood fibre insulating board*	11	0	0	4	16	9	10	2
Plywood (interior)*	0	0	0	4	14	8	10	3
Particle board	0	0	0	7	15	8	7	3
Timber -								
radiata pine	15	5	5	3	14	8	9	3
jarrah	13	3	4	2	13	5	4	2
Queensland hoop pine*	0	0	0	2	14	8	6	1
Plasterboard	12	0	2	3	13	0	3	2
Melamine laminate -								
bonded to non-combustible substrate*	0	0	0	3	14	8	5	3
bonded to combustible substrate*	0	0	0	3	14	8	4	4
Acrylic sheet	14	7	6	4	15	8	10	5
Glass fibre reinforced polyester sheet*	8	0	0	4	15	10	10	9
Polystyrene foam*	10	0	2	5	15	9	10	8
Polyurethane foam*	15	0	0	5	18	10	10	9
Rigid UPVC sheet*	0	0	0	5	13	2	1	8
PVC floor covering -bonded to non-combustible substrate*	14	0	0	4	17	9	5	7
Rubber floor covering - bonded to non-combustible substrate*	15	0	2	7	14	8	10	8
Linoleum	14	7	8	4	16	9	10	6
Acrylic carpet*	16	6	8	5	17	10	10	7
Carpet -								
100% wool	16	0	0	3	15	0	1	5
80% wool, 20% nylon	16	0	0	3	16	0	1	5
tiles 100% wool	16	0	0	3	15	0	1	5
tiles 80% wool, 20% nylon	14	0	0	5	15	7	5	7
tiles 100% nylon	14	7	9	7	16	8	10	7

I = Ignitability Index (0-20)

S = Spread of flame Index (0-10)

H = Heat Developed Index (0-10)

Sm = Smoke Developed Index (0-10)

The higher the index, the greater the hazard is likely to be from smoke.

The mechanism of smoke production

The combustion of solid materials in a fire involves the heating of materials and the release of hot combustible volatiles. These gaseous products ignite, rising above the fire as a column of flames and hot smoky gases.

The density of the column is lower than that of the surrounding colder air and consequently it moves upwards.

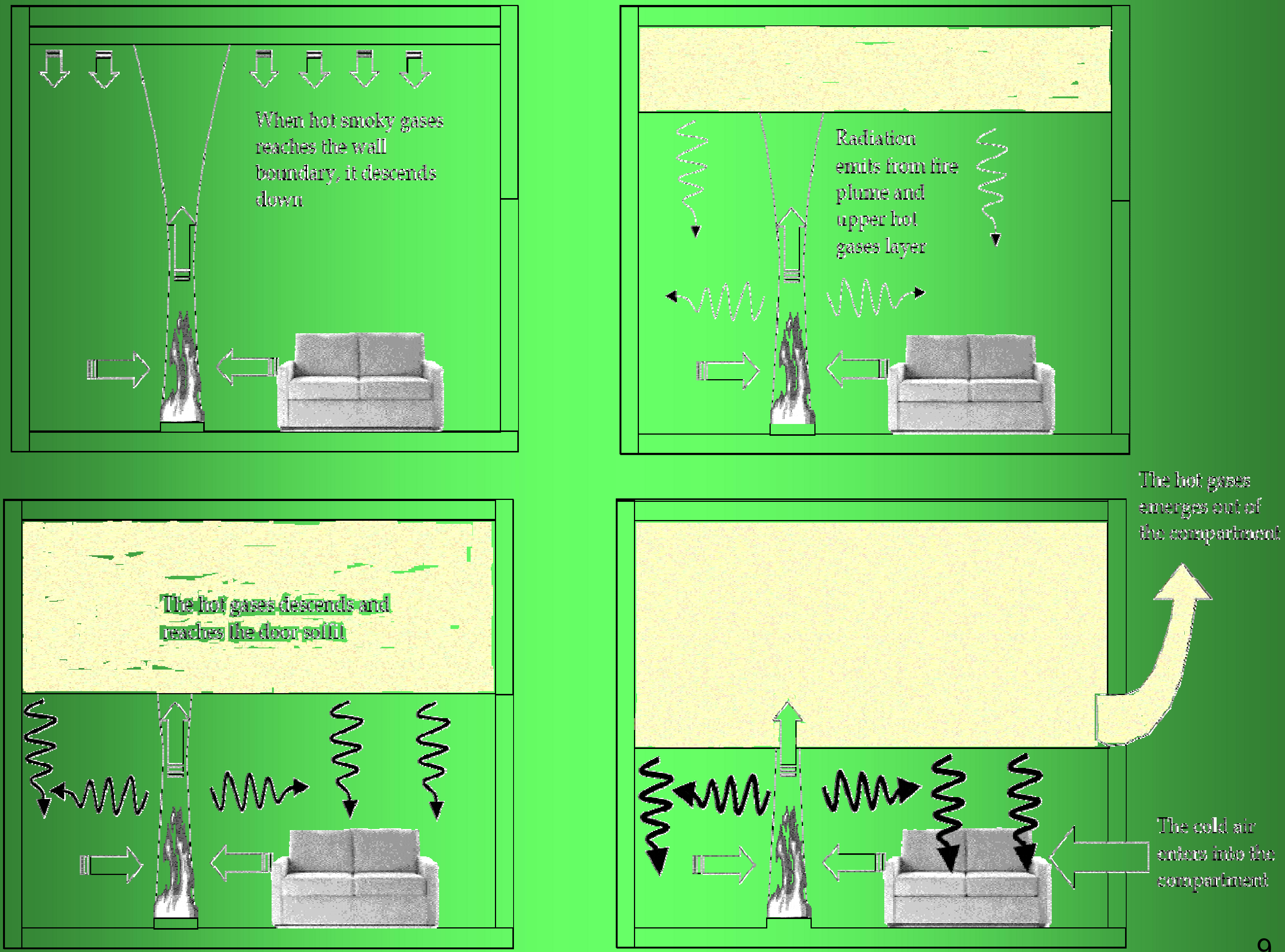
Incomplete combustion produce unburnt solid particles to form sooty smoke component. The excess air is heated and mixed with the hot smoky products of combustion to form a large inseparable cloud of smoke.

The rate of smoke production is approximately equal to the rate at which air is entrained by the rising column of hot gases and flames.

The volume of smoke produced

The rate of air entrainment into the column of hot gases and unburnt solid particles above the seat of a fire will depend on:

- the perimeter of the fire
- the heat output of the fire
- the effective height of the column of hot gases above the fire. This is, the distance between the floor of the room or space where the fire is and the bottom of the layer of smoke and hot gases which form under the ceiling of an enclosed space.


When hot smoky gases reaches the wall boundary, it descends down
Radiation emits from fire plume and upper hot gases layer
The hot gases descends and reaches the door soffit
The hot gases emerges out of the compartment
The cold air enters into the compartment

Smoke Densities

The smoke produced by fires varies considerably in nature and content.

It will vary in appearance from light-coloured to black and sooty, depending on the amount and type of unburnt particles in it and on the presence of coloured gases and condensation products. The quantity of smoke produced varies for materials.

The following quantities will produce enough smoke to fill a room of approximately $85m^3$ reducing the visibility to about 1m.

- 0.6 kg of timber (untreated)
- 0.08 kg of expanded polystyrene
- 0.12 kg of foam rubber
- 0.6 kg of polyurethane foam
- 0.35 litre of kerosene.

AS 1530.3-1989

Methods for fire tests on building materials, components and structures – Simultaneous determination of ignitability, flame propagation, heat release and smoke release

The smoke density is an important feature that needs careful consideration because it reduces visibility, thus hindering the progress of a person escaping from a fire.

Optical density is the logarithmic reduction of the intensity of light passing through a filter, in this case, through smoke.

Light obscuration and optical density can also be expressed as mathematical equations. Both are also interrelated so that the percentage of light obscuration can be converted to optical density.

Smoke Testing Apparatus

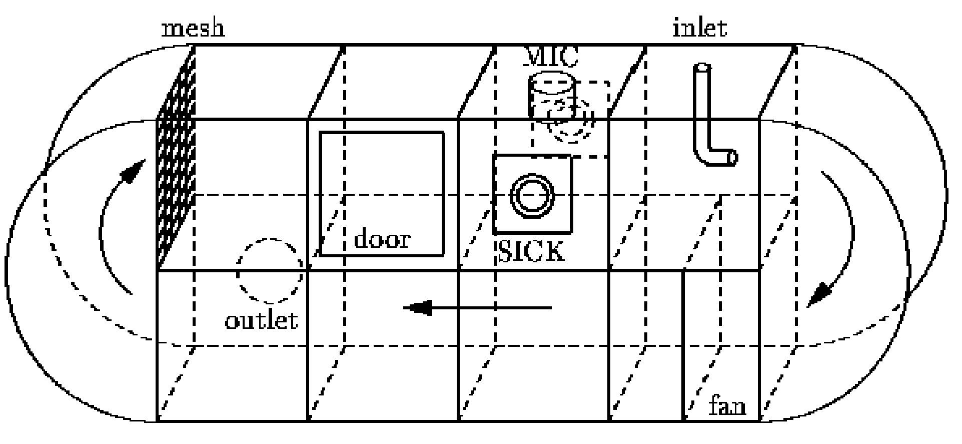
Smoke density The smoke density is produced by a paraffin oil generator.

Heat The duct is provided with a heating option. The testing of heat detectors according to EN 54-5 is not realised yet. For this purpose the heating concept would have to be upgraded to achieve a temperature rise of 30 K/min.

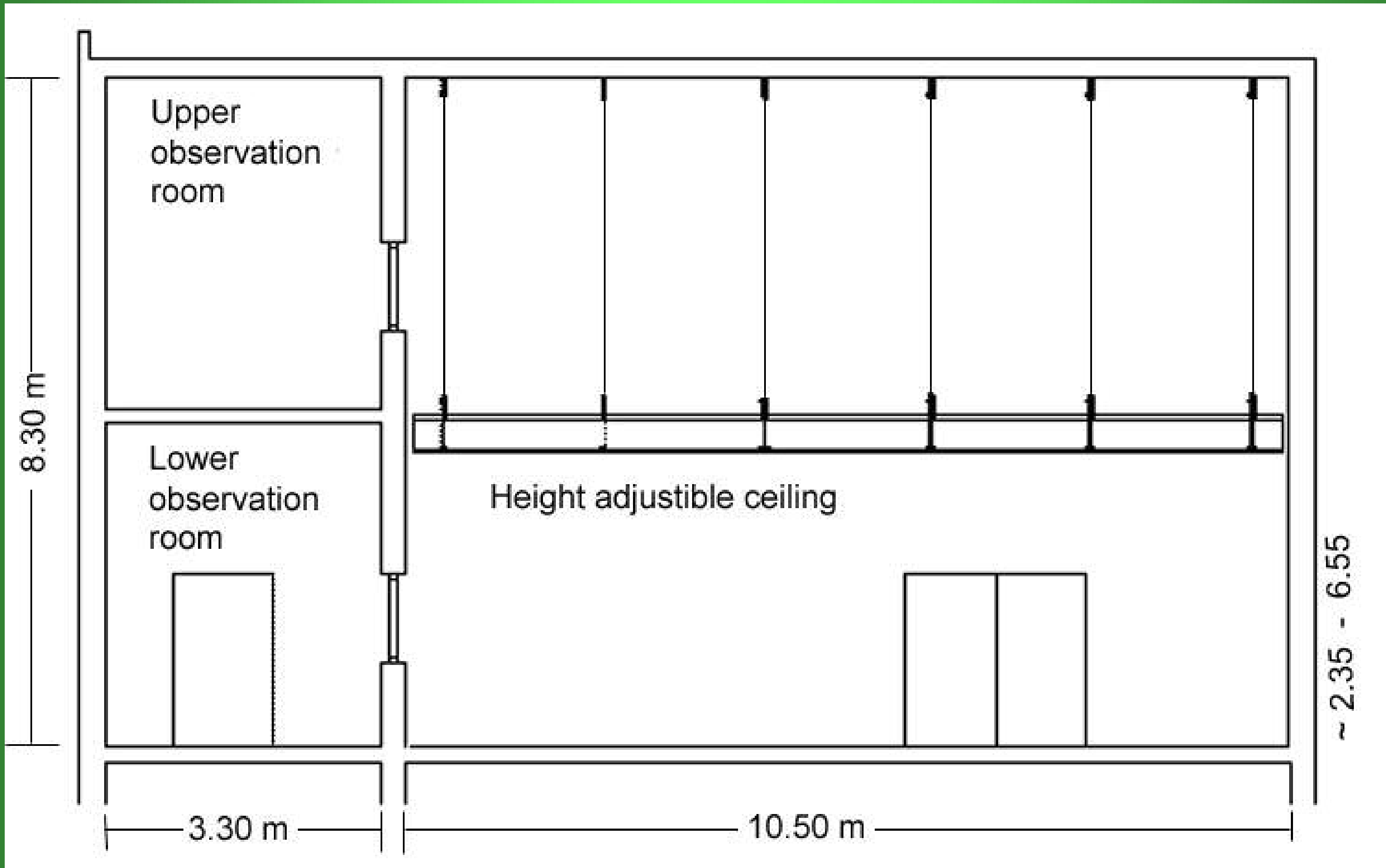
Gases The fire gases are produced by real fires (e.g. a cotton wick fire) by means of a simply constructed burning chamber; the smoke particles are filtered out. Additionally, there is the option to inject synthetic gases into the duct.

Dust It is possible to test the sensitivity of smoke detectors against dust. Standardized dust particles are injected into the smoke duct.

ISO dust A1: Ultrafine - dust particle with a nominal size of 0-10 μm
ISO dust A2: Fine - dust particle with a nominal size of 0-80 μm



Fire Detection Laboratory



Visibility

Visibility in smoke depends on many conditions:

- the colour of the smoke;
- the size of the smoke particles;
- the density of the smoke; and
- the irritant nature of the smoke are all characteristics which influence the degree of visibility.

The physical and mental state of the observer in panic or near-panic state of a real fire will affect visibility.

The comparative visibility of smoke produced by common building materials was established. These are shown in Table 1.

Table 1

Common building materials and comparative smoke visibility

Building board	Thickness (mm)	Visibility (m)
Wood-fibre insulating board	12.7	17.00
Phenol formaldehyde faced hardboard	4.0	5.20
Polyurethane foam sandwich	13.0	4.80
Softwood panels	6.4	4.30
Hardboard	3.7	4.10
Melamine-faced hardboard	3.2	4.00
PVC-faced hardboard	5.7	3.00
Rigid PVC panels	1.6	2.80
Chipboard	12.7	2.70
Glass-fibre reinforced polyester	3.3	1.50

The mechanism of smoke movement

The main factors that determine the movement of smoke and hot gases from a fire in a building are:

- the smoke's own mobility, or buoyancy,
- the normal air movement inside the building,

The movement caused by the smoke's mobility, or buoyancy is due to pressure differentials created by:

- the expansion of the gases as they are heated by the fire
- the difference in density between the hot gases and hot air above the flames and the cooler air surrounding the fire.

The normal movement of air in the building is usually caused by the following factors:

- the stack effect,
- the wind outside;
- the presence, or otherwise, of a mechanical air-handling system or mechanical ventilators inside the building.

Systems of smoke control

There are various methods and design arrangements for smoke control in buildings. These could be one of the following:

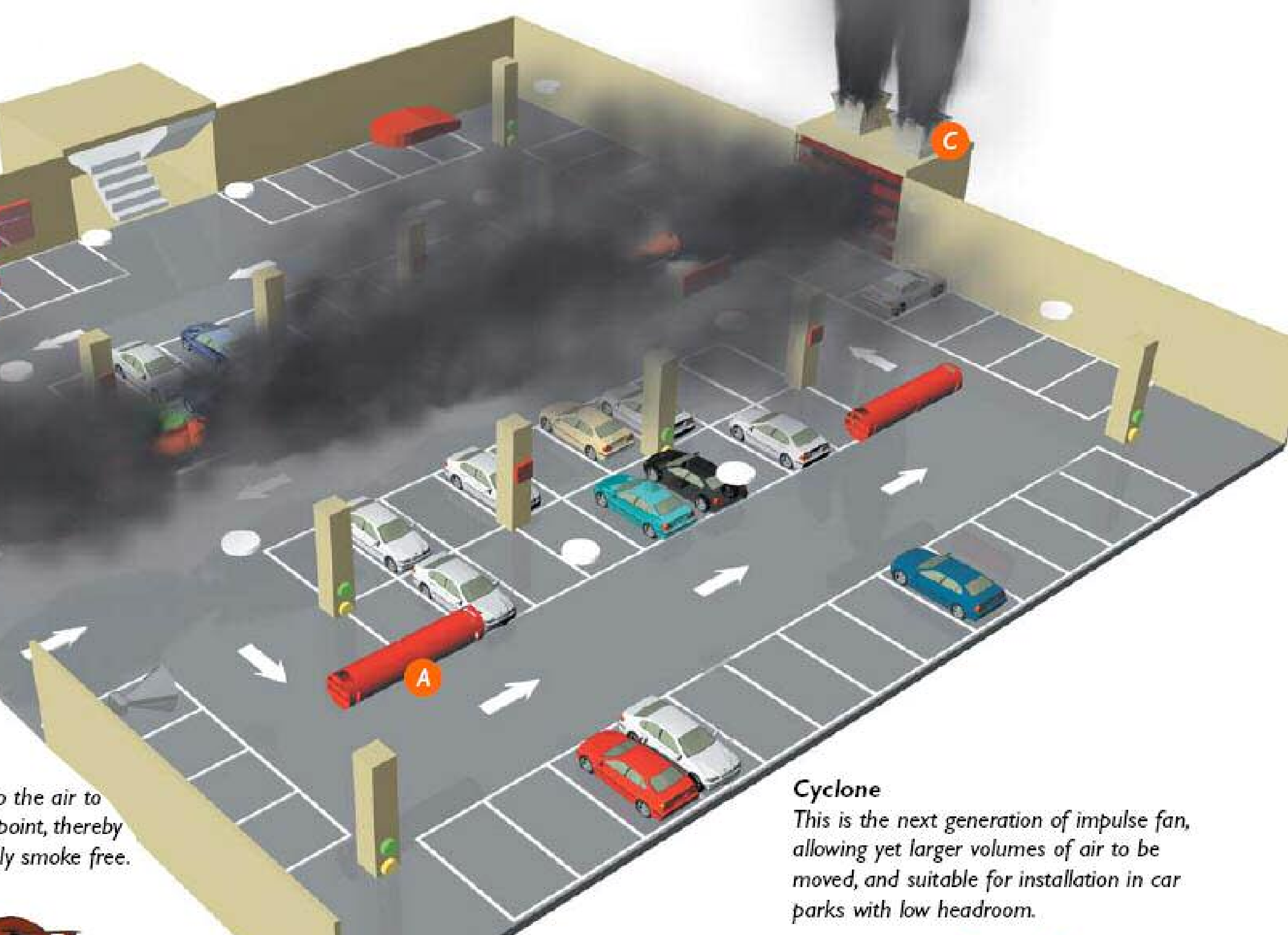
- take advantage of the natural forces of air movement to achieve the desired control and subsequent removal of the smoke
- rely on mechanical equipment and installations to guide the air and smoke along predetermined paths leading to a point of discharge outside the building.

Either system should be considered as a means of smoke control. The most efficient smoke control is generally obtained by employing both basic systems, natural and mechanical.

Mechanical extract systems

These are designed to exhaust smoke and exhaust gases.

C



Jetstream

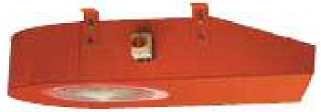
This unit adds momentum to the air to thrust it towards an extract point, thereby keeping large areas effectively smoke free.

A

Cyclone

This is the next generation of impulse fan, allowing yet larger volumes of air to be moved, and suitable for installation in car parks with low headroom.

B



Natural systems of smoke control

The layout and the arrangement of vertical and horizontal divisions can effectively control smoke within a building and also assist in its removal.

(Smaller and single-storey buildings represent lesser problems, whereas large high-rise buildings and complicated modern shopping complexes pose considerable problems for smoke control.)

The movement of smoke within a building will be influenced by many variables. It is practically impossible to try to stop the flow of smoke in a building altogether.

This is the case in large buildings, particularly high-rise buildings.

The more reasonable and realistic approach is to try to prevent the entry of smoke into the parts of the building that are not affected by the fire.

Cross ventilation

The simplest method for providing natural ventilation and evacuation of smoke from an enclosed space is the provision of openings in the external walls.

Cross-ventilation method for smoke disposal is mainly suitable for single-storey houses. The single-storey arrangement is particularly suitable for roof vents.

Keep the smoke in the upper reaches of the building and allow the unrestricted entry of fresh air.

In high-rise buildings vertical shafts are used as a means of smoke control and smoke extraction. In many cases special smoke shafts or smoke-ventilation ducts are provided.

In all cases the smoke should be discharged into the open and not recirculated within the building.

Air locks

Air locks or smoke lobbies prevent, or at least to reduce considerably, the entry of smoke into the defined fire-emergency exit system. When air locks protect the entrances to fire-isolated stairs, they may be arranged as:

- lobby-approach stair
- ventilated lobby-approach stair
- balcony-approach stair
- isolated tower stair.

Smoke lobbies are used as both natural and mechanical means for smoke control. The benefit is that in order to reach the exit system, the smoke has to pass through two sets of doors, across each of which a pressure opposing the smoke flow can be developed.

Smoke reservoirs

Smoke reservoirs can be provided by subdividing the underside of the roof of large single-compartment into separate catchment areas.

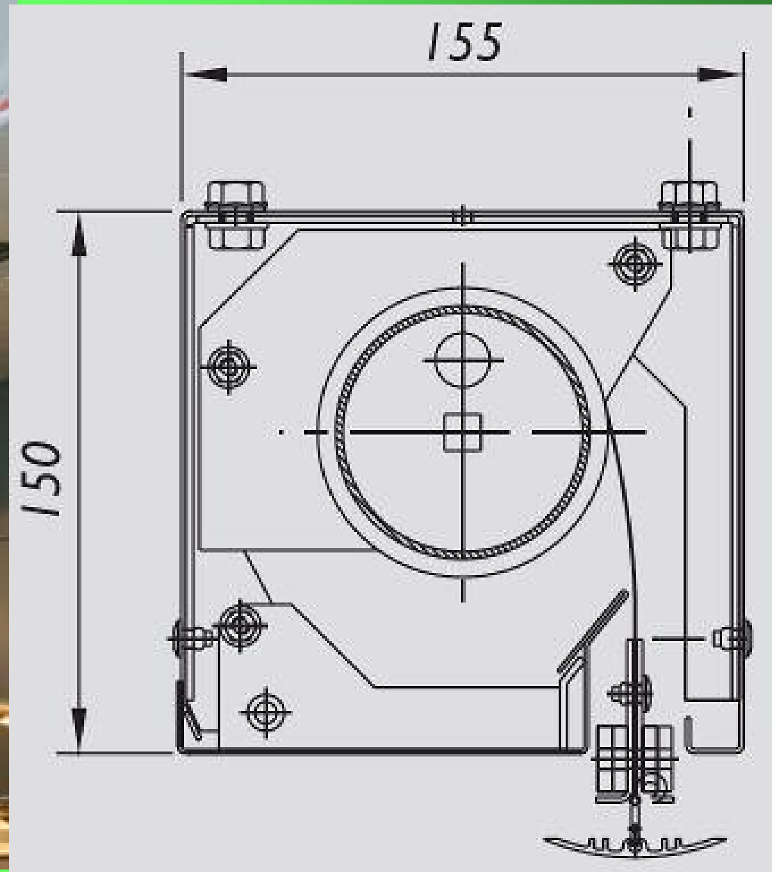
This can be done by suspending smoke curtains from the ceiling (roof).

Such lightweight non-combustible smoke curtains form inverted reservoirs at ceiling level that entrain the smoke and hot gases directly over the seat of the fire and for a certain period of time prevent its further spread at ceiling level.

Vents are installed in these catchment areas (smoke reservoirs) to exhaust the collected smoke directly to the outside atmosphere.

Automatic Smoke Curtain

Smoke containment systems prevent the movement of smoke and heat from one area to another.



The roller assembly contains all the electronic components. All Smokemaster curtains require a 230 V ac power source.

Fire door or smoke door

Smoke doors automatically seal off the flow of smoke through the particular doorway protected by such a door.

The smoke door is not necessarily a fire door and is very often of lightweight construction and may be combustible.

Its only function is to prevent, or at least restrict, the passage of smoke whereas a fire door will stop the passage of fire.

The important requirement for a smoke door is that such a door must be closed automatically by the action of a smoke detector.

Fire Doors

Fire doors are designed to withstand fire, heat and smoke for a period of 20-minutes to 3 hours.

Did you know that corridor office doors are fire doors and should have a fire rating?

Corridor laboratory doors should have a 60 minute rating.

Fire Doors are required to:

- Be Self Closing: fire doors should have a door closure that pulls doors completely shut after the door has been opened

- Have Positive latching: a positive latch locks a door in place so can open swing open freely.

Power-operated units

Mechanical systems of smoke control

The mechanical extraction of smoke and the arrangements for providing higher atmospheric pressure in certain parts of a building are used to increase the efficacy of natural smoke control. A mechanical system of smoke control could be:

- power-operated units for smoke extraction or for fresh-air supply
- a particular operation of the air-handling system, or air conditioning, in a building fitted with such a system
- pressurisation of certain parts of a building, principally the defined fire emergency exit system(s).

They must operate with emergency electrical power as the normal power supply could not be relied upon during a building fire.

A pressurisation system can be used:

- only in the event of a fire with provisions for automatic and manual starting
- at full operation when the building is occupied
- at reduced capacity when the building is normally occupied with an automatic and manual boost to full operation in the event of a fire.

During a fire situation the necessary electrical power is to be supplied from an emergency power source.

Smoke control in large buildings

1. Air-handling systems and pressurisation of the fire-emergency exit are particularly suitable.
2. Smoke curtains in the roof space and the various types of roof vents are better suited to large single-storey buildings.
3. The types of roof vents that may be used are:
   - permanently open vents usually fitted with fixed louvres
   - vents that are set to open automatically when actuated by a detector – usually opened by a gravity or spring action
   - combustible roof skylights made of plastics with a low melting temperature, so that when this skylight melts the hole in the roofing acts as a vent opening.

Smoke modelling computer packages

A number of commercial software packages are available in Australia. They use accepted models which can help in the prediction of fire growth and movement, they are:

- Firecalc – developed by the CSIRO
- Yardstick – developed by the University of Adelaide.

These are specialist programs for use by fire engineers. It should be remembered that they only give indications and cannot be regarded as being a true reflection of fire outcomes in every instance.

Smoke Production and Handling

The rate of air entrainment into the column of hot gases and unburnt solid particles above the seat of a fire will depend on:

- the perimeter of the fire
- the heat output of the fire
- the effective height of the column of hot gases above the fire.

  This is, the distance between the floor of the room or space where the fire is and the bottom of the layer of smoke and hot gases which form under the ceiling of an enclosed space.

The Mechanism of Smoke Movement

The smoke’s own mobility, or buoyancy, which is due to the fact that the hot gases and the hot air in the cloud of smoke are less dense than the surrounding air

The normal air movement inside the building, which may have nothing to do with the fire, but which could carry the smoke around that building.

The Mechanism of Smoke Movement

The movement caused by the smoke's mobility, or buoyancy is due to pressure differentials created by:

The expansion of the gases as they are heated by the fire

The difference in density between the hot gases and hot air above the flames and the cooler air surrounding the fire.

Smoke Movement

The normal movement of air in the building is usually caused by the following factors:

- The stack effect or the pressure differential due to the air inside the building having a different temperature from the air outside.
- The wind outside; all buildings are to a greater or lesser extent leaky or have openings to the outside.
- The presence or otherwise, of a mechanical air-handling system or mechanical ventilators inside the building.

Safety precautions

Rapid spread of fire and smoke requires technical investigation to determine how the life safety features of building may have impacted egress

Examination of parameters that affected egress, including hazard recognition and response, location and identification of exits, condition of exits, and changing conditions inside structure (i.e. smoke and heat build-up, loss of lighting)

Evaluate smoke control in buildings

Research psychological effects of smoke on people exposed to building fires.

Record and identified mechanisms of smoke movement in building.

Identified smoke control systems that meet the requirements for buildings in accordance with legislative requirements.

Analyse the application of computer packaged smoke control systems.

BCA General Requirements

Paragraph 2 of Specification C1.10 prescribes that any material (other than a sarking) or component used in a Class 2, 3, 5, 6, 7, 8 or 9 building must have

(a) a Spread of flame Index not more than 9; and

(b) a Smoke developed Index not more than 8 if the Spread of flame Index is more than 5.

Fire Isolated Exits

Paragraph 3 prescribes the requirement of materials used in fire-isolated stairways, passageways, ramps or lift shafts in Class 2 to 9 buildings. These materials must -

(a) have a Spread of flame Index of 0; and

(b) have a Smoke developed Index of not more than 2.

(c) if combustible, be attached directly to a non-combustible substrate and not exceed 1mm in finished thickness; and

(d) have a Flammability Index of 0 (for Sarking-type materials used as an exposed wall or ceiling or as a finish or attachment there-to).

What do we know about the fire performance of plastics in fire?

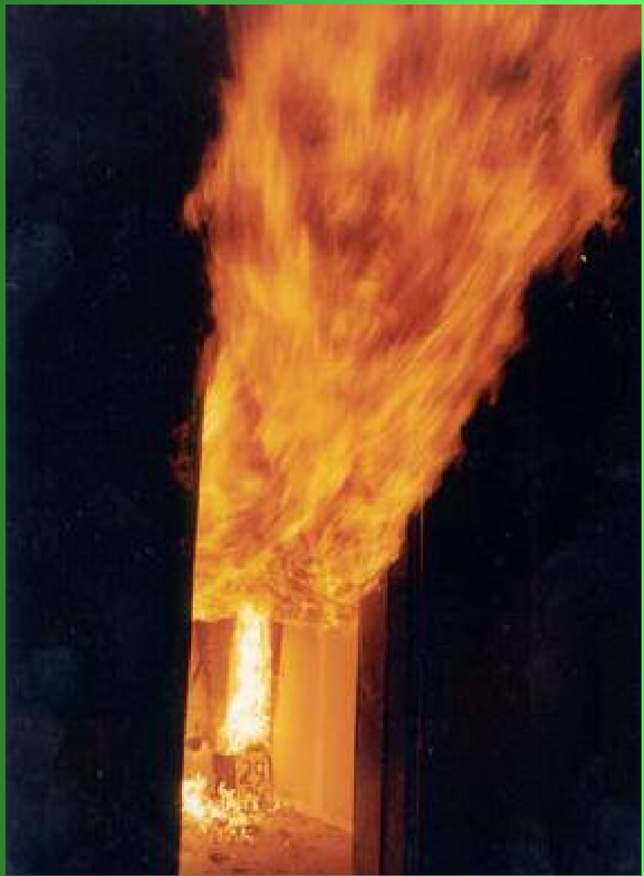
Reaction to fire

Testing in relation to reaction to fire, deals specifically with parameters such as:

- Ease of ignitability,
- Flammability,
- Spread of flame characteristics,
- Heat evolved
- Smoke
- Toxicity

Properties relate to the contribution of a plastic material to the smoke of a fire that has already started.

Testing in this area is applicable for wall and ceiling lining materials.



ISO 9705 Intermediate scale room corner test designed for testing spread of fire properties and smoke evolved properties of wall and ceiling lining material assemblies
(photo courtesy of CSIRO-MIT)

Paraphen reinforced phenolic sheet material being tested at small scale level for spread of fire properties (photo courtesy of Alsynite Specialty Products)

Expandable Polystyrene (EPS) Sandwich panels

If a fire starts and the EPS sandwich panels themselves get involved in the fire, the fire can spread very quickly.

The correct installation practices and proprietary panel types must be used.

Specific fire protection systems may be applied, otherwise the fire can cause serious damage to a facility.

Generic plastic types

Thermoplastic and Thermoset type plastics.

Thermoplastic type plastics soften when heated and reharden when cooled. The process is reversible. These plastic materials typically melt and burn in fires.

Some examples include acrylic plastics, polycarbonate, PET (Polyethylene terephthalate), PVC and EPS (expanded polystyrene).

Thermoset plastics cure and the process is irreversible. They do not soften and reharden on cooling. When they burn they typically char.

Examples include Polyurethane, (PU),Polyisocyanurate, (PIR), Fibre Reinforced Plastics, (FRP) and Phenolics.

External Insulation and Finishing Systems (EIFS)

This is a relatively new construction practice that is popular in Europe and the USA, and involves polystyrene insulation with polymeric render over the top of it.

Note 1 - EIFS containing EPS with a thickness greater than 25 mm adhered to a plasterboard substrate is considered combustible construction.

There are obviously on going maintenance issues for life of building to ensure the EPS is covered as some of these systems have been known to be subject to impact damage and damage from flying debris in storms.

(a) Corner test being conducted on EPS sandwich panel construction

(b) Corner test being conducted on EPS sandwich panel construction

Standards

ISO 5660-2:2002

Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part 2: Smoke production rate (dynamic measurement)

AS/NZS 1530.3:1999 :

Methods for fire tests on building materials, components and structures - Simultaneous determination of ignitability, flame propagation, heat release and smoke release

AS/NZS 4256.1:1994 :

Plastic roof and wall cladding materials - General requirements

AS/NZS 2785:2000 :

Suspended ceilings - Design and installation

AS 60695.6.1-2006 :

Fire hazard testing - Smoke obscuration - General guidance

AS 4655-2005 :

Fire safety audits

Sets out requirements for auditing fire safety measures against nominated audit criteria, including those relating to life safety. Includes general principles of auditing, audit program management, the fire safety audit process and responsibilities, reporting, fire safety audit levels, audit team competence evaluation of auditors and derivation of fire safety audit criteria.

ATS 5387.2-2006 :

Guidelines - Fire safety engineering - Design fire scenarios and design fires

Sets out guidance on the identification of appropriate design fire scenarios for consideration in fire safety design and provides guidance on the specification of design fires for quantitative analysis in fire safety design of buildings.

The "stick-framed" Virginia Commonwealth University student apartment building on West Broad Street was going up in a fire. On March 26, it really went up in hurry. It took just a half-hour for the top four floors of the blocklong building to be consumed in a wind-whipped inferno that spread to 26 buildings on nearby blocks.

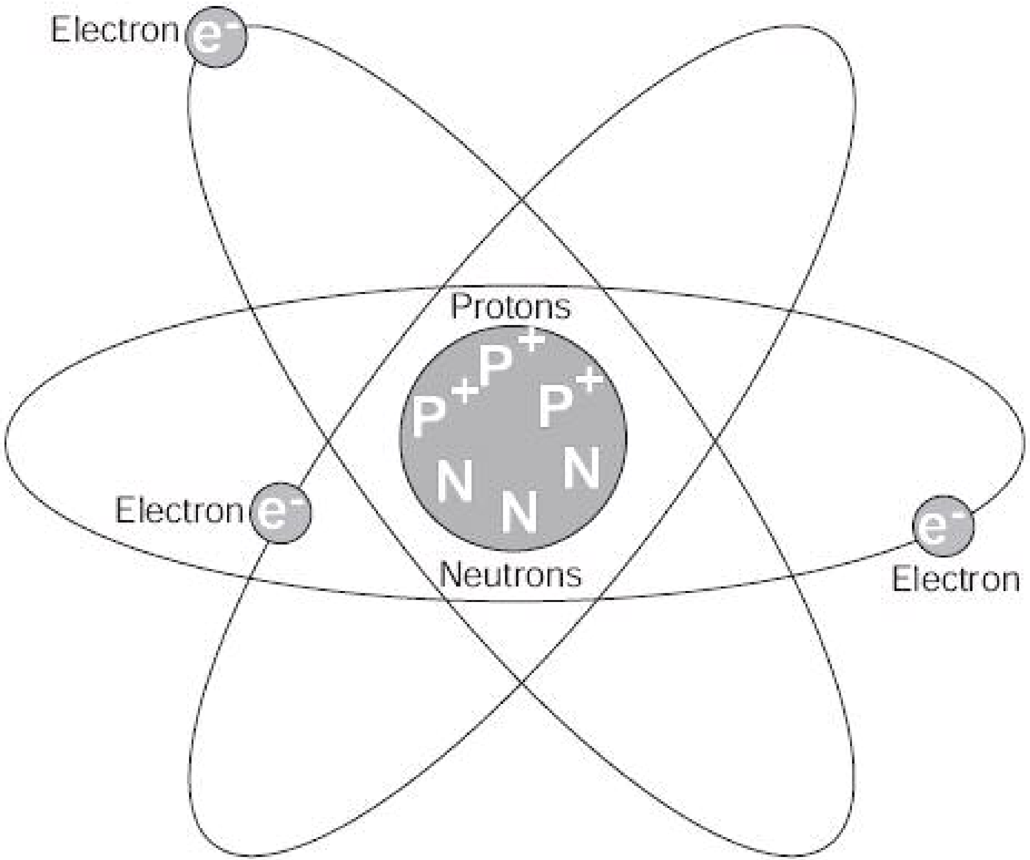
The student apartments did not meet the city's building code, Richmond Building Commissioner Claude Cooper

http://www.dailyprogress.com/servlet/Satellite?pagename=RTD/MGArticle/RTD_BasicArticle&c=MGArticle&cid=1031774528676

Thanks for your attention

Virginia Commonwealth University student apartment building on West Broad Street

Fire fighter fighting one of the house fires on West Clay St.


Electron
e-
Protons
P+
P+
P+
N
N
N
Neutrons
Electron
e-
e-
Electron

If calcium hydroxide is heated, it will form calcium oxide and water. The change in heat required is

+ 65.1 kJ.

Again, chemically this would be represented in the following manner

$$Ca(OH)_2 \quad CaO + H_2O \qquad \Delta Hf = + 65.1\ kJ.$$

This shows that there are 65.1 less kJ of energy tied up in the compounds on the left hand side of the equation than in the products on the right hand side. This means that the calcium hydroxide had to be heated before the reaction took place.

Calcium - Ca

Atomic number 20
Atomic mass 40.08 g.mol -1
Mass volume 1.6 g.cm-3 at 20°C
Melting point 840 °C
Boiling point 1484 °C
Vanderwaals radius 0.197 nm
Ionic radius 0.099 nm
Isotopes 10
Standard potential- 2.87 V
Discovered Sir Humphrey Davy in 1808

Oxygen - O

Atomic number 8
Atomic mass 15.999 g.mol -1
Melting point-219 °C
Boiling point-183 °C
Vanderwaals radius 0.074 nm
Ionic radius0.14 nm (-2)
Isotopes4
Electronic shell [He] 2s 2 2p 4
Energy of first ionisation 1314 kJ.mol -1
Energy of second ionisation 3388 kJ.mol -1
Energy of third ionisation 5300 kJ.mol -1
Discovered by Joseph Priestly in 1774

Hydrogen - H

Atomic number 1
Atomic mass 1.007825 g.mol -1
Density 0.0899*10 -3 g.cm -3 at 20 °C
Melting point - 259.2 °C
Boiling point - 252.8 °C
Vanderwaals radius 0.12 nm
Ionic radius 0.208 (-1) nm
Isotopes3**Electronic shell** 1 s1
Energy of first ionisation 1311 kJ.mol -1
Discovered by Henry Cavendish in 1766*

Periodic Table of the Elements

Alkali metals	Alkaline earth metals	Transition metals	Lanthanide series	Actinide series	Poor metals	Nonmetals	Noble gases

C Solid · Br Liquid · H Gas · Tc Synthetic

New: 1–18; Original: IA–VIIIA

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 —	9 VIIIB	10 —	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.989770	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.8457	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 to 71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 to 103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium

Atomic masses in parentheses are those of the most stable or common isotope.

57 La Lanthanum 138.9055	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

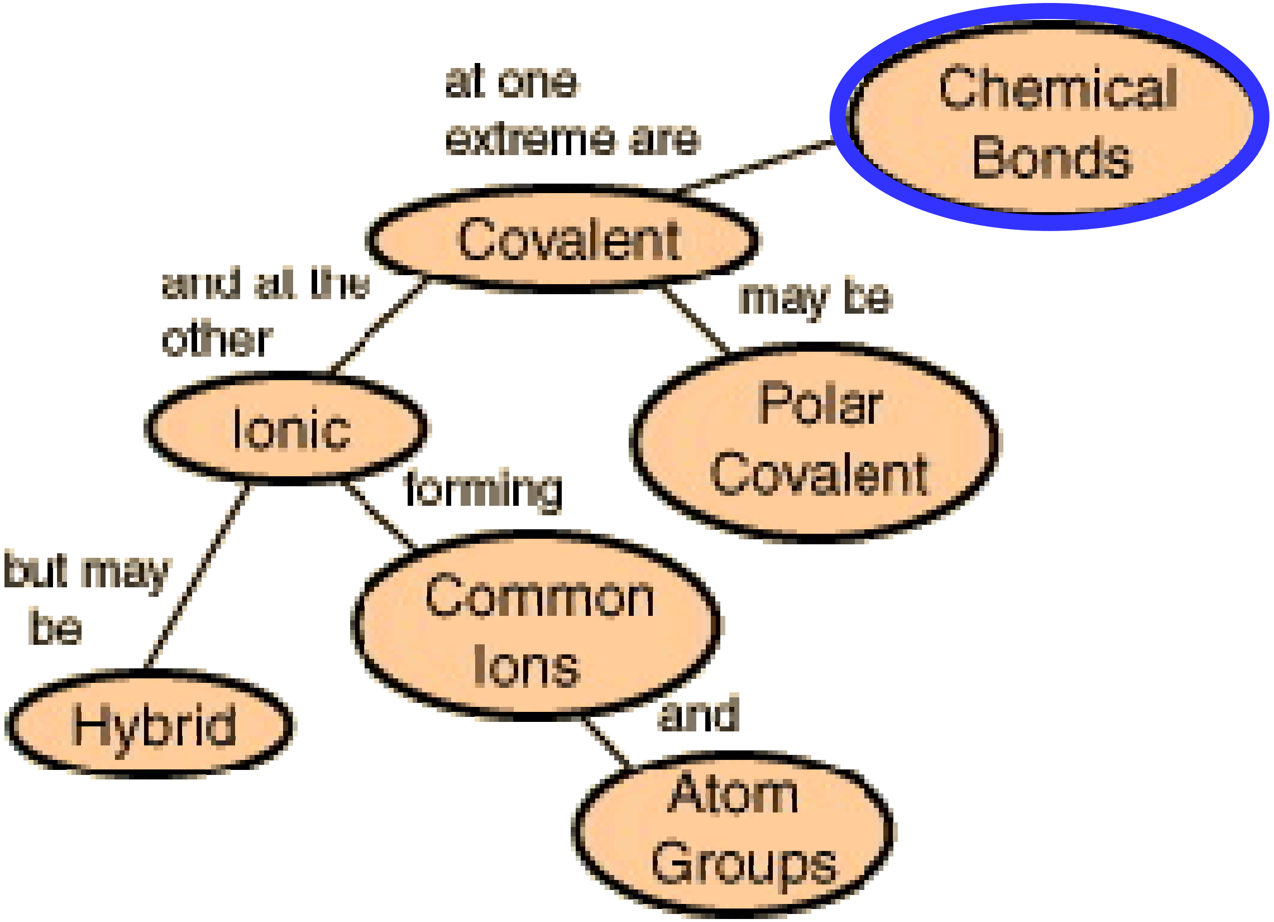
A COVALENT BOND results when two atoms "share" valence electrons between them.

Carbon forms covalent bonds

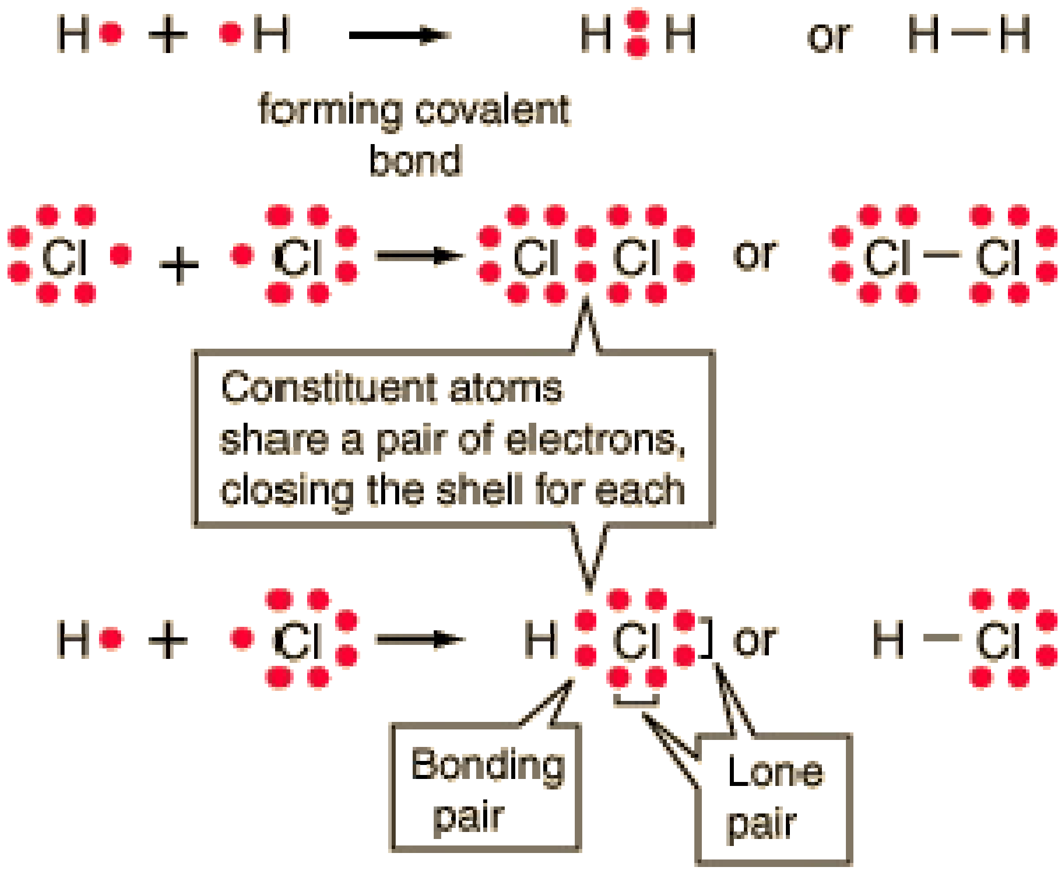
An IONIC BOND occurs when one atom gains a valence electron from a different atom, forming a negative ion (ANION) and a positive ion (CATION), respectively. These oppositely charged ions are attracted to each other, forming an ionic bond.

example is table salt, sodium chloride

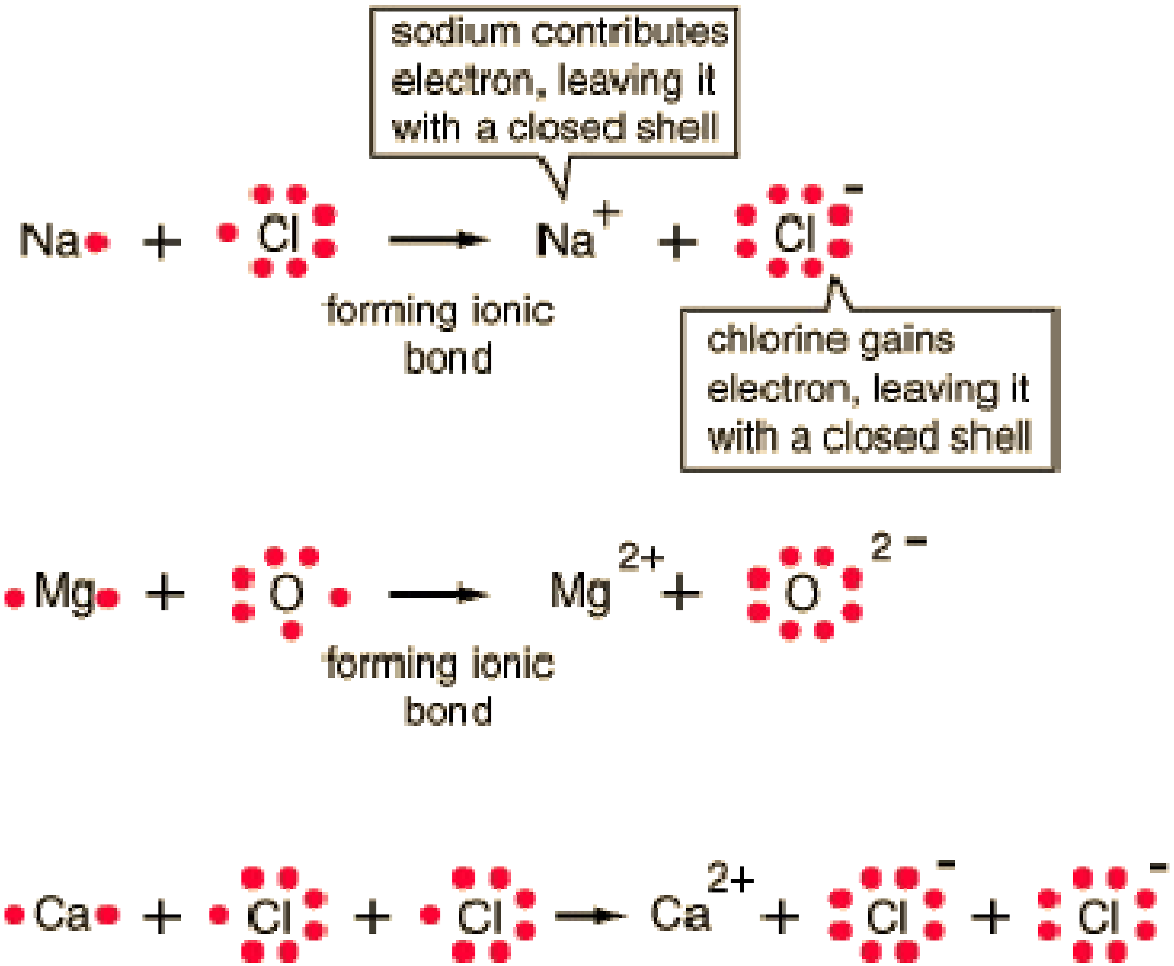
METALLIC BONDING usually occurs in metals, such as copper. A piece of copper metal has a certain arrangement of copper atoms. The valence electrons of these atoms are free to move about the piece of metal and are attracted to the positive cores of copper, thus holding the atoms together.


Chemical Bonds
at one extreme are
Covalent
and at the other
Ionic
may be
Polar Covalent
forming
but may be
Common Ions
Hybrid
and
Atom Groups

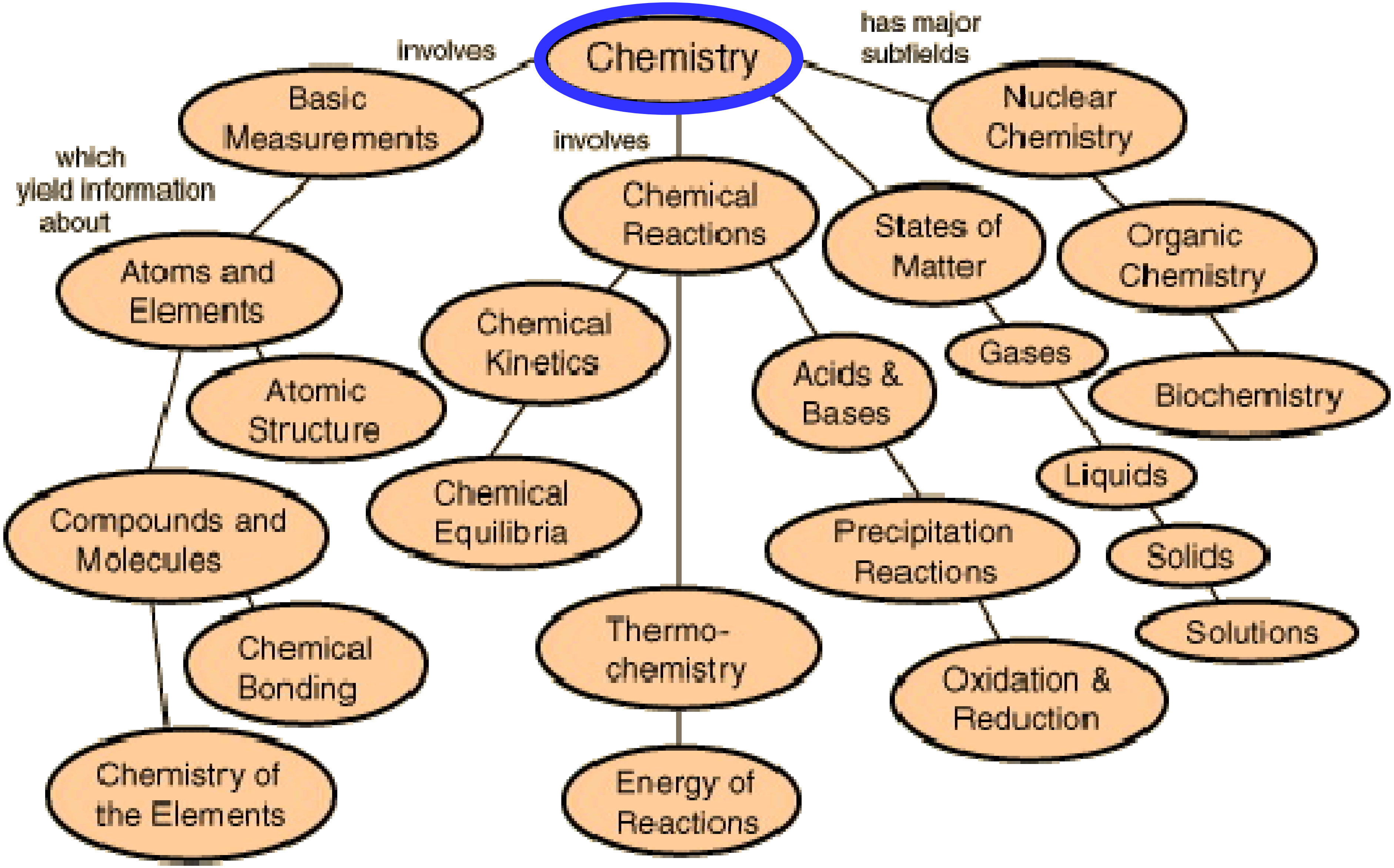
Covalent Bond



Ionic Bond



sodium contributes electron, leaving it with a closed shell
Na + Cl → Na+ + Cl-
forming ionic bond
chlorine gains electron, leaving it with a closed shell
Mg + O → Mg2+ + O2-
forming ionic bond
Ca + Cl + Cl → Ca2+ + Cl- + Cl-


Chemistry
involves
has major subfields
Basic Measurements
which yield information about
Atoms and Elements
Atomic Structure
Compounds and Molecules
Chemical Bonding
Chemistry of the Elements
involves
Chemical Reactions
Chemical Kinetics
Chemical Equilibria
Thermo-chemistry
Energy of Reactions
Acids & Bases
Precipitation Reactions
Oxidation & Reduction
States of Matter
Gases
Liquids
Solids
Solutions
Nuclear Chemistry
Organic Chemistry
Biochemistry