Chapter 6

Pulm nary health hazards in manual welding perati n in c nstructi n: a study n engineering c ntr l measures

1 Intr ducti n:

Welding is a metallurgical process that joins materials, usually metals or thermoplastics, by causing coalescence This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld

In construction work involving structural steel and pipelines, welding is an important process such as pipe welding, structural steel fabrication, structural steel welding etc

The electric arc is struck between the electrode and the work piece, or between two electrodes It is usually necessary to add some molten metal to the joint and this is done either by,

- melting the electrode itself, consumable electrode processes; or
- melting a separate filler rod which is not carrying current, non-consumable electrode processes

Welding operation adopted is hazardous in nature and classified as hot work Hot work activities, such as welding and gas cutting, involve the use of heat Besides health hazards due to exposure to welding products including fumes, sparks etc The flames, sparks and heat produced during the hot work are ignition sources which can cause fires and explosions in many different situations

Exposure to welding fumes can cause numerous health problems When inhaled, welding fumes can enter the lungs, bloodstream, brain nerve cells, spinal cord and other organs and can cause both short- and long-term health effects Many welders who work in factories or in the construction, ironworks,

manufacturing, mining, metallurgy, petrochemical, railroad, shipbuilding or steel industries, most suffer from some sort of respiratory illness or pulmonary infection In construction industry such welding operations are carried in a covered booth like set ups which results in buildup of welding smoke in the working zone

Engineering challenge: There are no proven effective methods to ensure a proper ventilation system which could be incorporated on the work areas Owing to the dynamic nature of the task and magnitude of welding for the mechanical jobs in industrial construction work this requirement gets overlooked Hence there is a scope for a study in this area to arrive at an effective engineering intervention for reducing adverse health impacts

1 Potential exposure associated with various welding processes

Pr cess	**P tential Exp sure**
SMAW	Excessive fume concentration and fluoride (MS);chromium and nickel (SS)
FCAW	Excessive fume levels
Air carbon arc/ Plasma arc cutting	Excessive fume; noise
Oxy-gas cutting	Production of carbon monoxide or oxides of nitrogen
Thermal spraying	Excessive fume levels of sprayed metal, eg zinc
Confined spaces	Oxides of nitrogen

Contents of the welding fumes depend on the components of the base metal, coatings and/or filler materials and the temperatures used in the welding process Types of metals commonly found in welding fumes include aluminum, beryllium, cadmium oxides, chromium, copper, fluorides, iron oxide, lead, manganese, molybdenum, nickel, vanadium and zinc oxides Types of gases, includes carbon monoxide, fluorine, hydrogen fluoride, nitrogen oxide, ozone[3] etc

Since such fumes and gases could be hazardous to worker health It is necessary to study the chemical characteristics of these chemicals suitably to find out suitable mitigation measures

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2 Materials used in welding

1 C re and filler metals

Generally, core and filler material are of identical alloy in chemical composition to the material being welded Most commonly used material is mild steel Special steels may contain chromium, nickel, aluminum, or tungsten etc Stainless steel electrodes may contain up to 26 per cent chromium and 21 per cent nickel

2 Electr de c atings (fluxes)

We understand from research papers that complex mixtures are coated with MMAW electrodes generates the following during welding:

- cellulose, carbonates various metals or their oxides, calcium fluoride etc
- oxides of titanium, silicon, manganese and magnesium
- Readily ionisable elements such as sodium, potassium, calcium etc

Electrode coatings may also include ferro-manganese, ferro-vanadium and ferro-silicon

Electrode coatings in certain instances may have substantial amounts of metallic constituents added which contribute to the weld deposit, for example, iron, manganese, chromium and nickel

Welding Pr cess :

Before studying the health hazards of welding fumes, we need to understand various Welding Processes which are as given below:

6231 Health hazards related to various manual welding processes:

6232 Manual metal arc welding (MMAW)

The flux material of MMAW while vaporizing it forms a shielding gas (carbon dioxide) to protect the cooling weld deposit from the air

Low-hydrogen MMAW electrodes contain a high amount of fluoride which facilitates complete drying, but at the same time also acts as an arc suppressant, thereby necessitating higher operating arc voltages

624 Non-consumable electrode processes

6241 Gas tungsten arc welding (GTAW)

A shield of inert gas is used to protect the arc zone and the weld metal from the air, thus preventing oxidation and contamination of the metal The electrode is of tungsten and the inert shielding gas is argon, helium or a gas mixture The electrode contributes no metal to the weld, but weld metal may be added by means of a suitable uncoated filler rod

Examples of welding gases:

Gases used in welding and cutting processes include:

1. Shielding gases such as carbon dioxide, argon, helium, etc
2. Oxygen, used with fuel gases and also in small amounts in some shielding gas mixtures

Gases produced from welding and cutting processes include:

3. Carbon dioxide from the decomposition of fluxes
4. Carbon monoxide from the breakdown of carbon dioxide shielding gas in arc welding
5. Ozone from the interaction of electric arc with atmospheric oxygen
6. Nitrogen oxides from the heating of atmospheric oxygen and nitrogen
7. Hydrogen chloride and phosgene produced by the reaction between ultraviolet light and the vapours from chlorinated hydrocarbon degreasing solvents (eg, trichloroethylene, TCE)

Gases are also produced from the thermal breakdown of coatings:

8. Polyurethane coatings can produce hydrogen cyanide, formaldehyde, carbon dioxide, carbon monoxide, oxides of nitrogen, and isocyanate vapours
9. Epoxy coatings can produce carbon dioxide and carbon monoxide
10. Vinyl paints can produce hydrogen chloride
11. Phosphate rust-inhibiting paints can release phosphine during welding processes
12. Minimizing exposure to degreasing solvent vapours

625 Fume in welding processes

6251 Fume formation

Welding process generates considerable amount of welding fumes Due to the high temperature of welding arc constituents of core metal and flux reacts which eliminates fume particles consisting a mixture of complex oxides etc Formation of welding fumes due to product of reaction of core and flux components will depend on the following:

- welding conditions, which influence arc and gas temperatures;
- heats of formation, a thermochemical factor; and
- relative volatilities, that is, vapourisation behaviour, of the metal oxides, etc

In certain cases, materials other than the welding consumables may represent a significant source of atmospheric contamination Some examples are:

- where the work-piece itself contains volatile constituents, such as beryllium in copper;

where alloys have a surface coating (see the section on welding processes and materials), or where non- ferrous metals, such as copper and nickel or their alloys, are cut, heated or welded; and

- where painted metal surfaces are used, metal fumes may result from the paint pigment and organic pollutants from the paint binder

2 Health Hazards of Metal Fumes

Metal Fumes	**S urce**	**Implicati ns**
Aluminum	Alloys, eg, Inconels, copper, zinc, steel, magnesium, and brass and filler materials	Respiratory irritants
Lead	welding / cutting of metal that which may contain lead in different forms	In general lead poisoning is rare in welders unless if they are involved in such operations which involve exposure to lead which may be in different forms with the metal
Cadmium	Coating of certain element that is being welded	Acute irritation of the respiratory passages, bronchitis, chemical pneumonia or excessive fluid in the lung tissues (pulmonary oedema)
Manganese	Electrode cores, coatings or in electrode wire	Respiratory tract irritation, Acute lung inflammations
Zinc	Galvanized steel contains zinc	Metal fume fever, zinc chills
Iron	ferrous alloy welding	Deposition of iron oxide particles in lungs This condition is also called as siderosis
Molybdenum	steel alloys	Bronchial irritation and moderate fatty changes in the liver and kidneys
Cobalt	High-strength, high-temperature alloys	Shortness of breath, coughing and pneumonitis
Vanadium	Filler wires and special alloy steels	Severe irritation of the eyes, severe throat and respiratory tract irritation, and may also cause chemical pneumonia
Nickel	Nickel-plated mild steel, and stainless steel and high-strength low-alloy steel electrodes	Irritation of the respiratory tract
Chromium	Coating on the work piece in stainless steel and chrome-alloy electrodes	Irritant to the mucosal tissue in the respiratory tract
Fluorides	MMAW, FCAW and GMAW operations and SAW fluxes	Irritation of the eyes, throat, respiratory tract and skin

3 Health Hazards of Gases

Metal Fumes	**S urce**	**Implicati ns**
Oxides of nitrogen	Direct combination of oxygen and nitrogen in the air surrounding the arc or flame, as a result of heat from the electric arc or gas torch (oxidizing flames) In confined spaces, hazardous concentrations of nitrogen oxides may rapidly build up in welding operations High concentrations of nitrogen oxides have also been found during gas tungsten-arc cutting of stainless steel	excessive fluid in the lung tissues (pulmonary oedema)
Carbon monoxide	Through carbon dioxide-shielding atmospheres by reduction of shielding gas, and to a much lesser extent in all welding of steel by partial oxidation of carbon in the consumables Carbon monoxide will also be produced in gas welding when combustion of acetylene is incomplete, as with a reducing flame Carbon monoxide levels may build up in confined spaces and poorly ventilated spaces	Overexposure may cause drowsiness, headache and nausea If carbon monoxide exposure is sufficiently severe, unconsciousness may occur
Carbon dioxide	Common in GMAW	Can cause asphyxiation
Phosphine	steel coated with a rust proofing compound is welded	High concentrations of phosphine gas are irritating to the eyes, nose and skin There may also be serious effects on the lungs and other organs
Insufficient oxygen	In GMAW, the presence of inert gases (argon, helium) in confined work environments may reduce the oxygen content of the atmosphere to dangerous levels,	Can cause asphyxiation

3 Welding in c nstructi n industry: Challenges

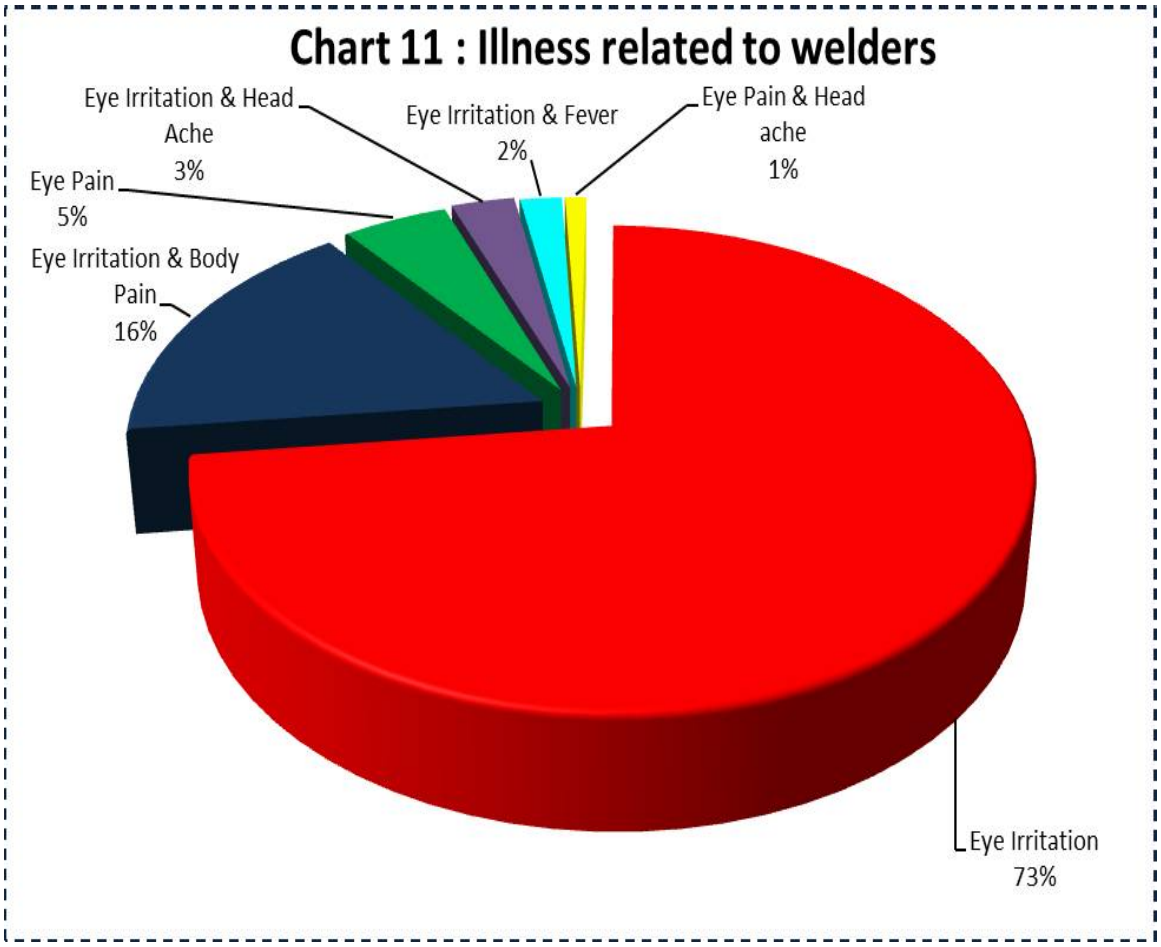
As already discussed, welding in construction industry is different in various ways including its arrangements, in comparison to any organized sector Implementation of any specific control measures generally may be difficult or not possible due to various practical limitations and job-specific diversities In view of the dynamics of construction activities, including changing job patterns, welding process represent complex challenges This includes the nature of work such as work at height for eg, on structures, pipe racks, equipment, etc Welding sometimes take place at below ground level in excavated pits or tunnels for example during welding of underground pipes, utilities etc In some instances such welding operations are also carried on inside confined space In all the above mentioned cases each activity differs in terms of control measures Such welding operations at construction sites are ideally to be carried out by providing an enclosed booth-like set-up to prevent the ingress of oxidization material (air) during welding Since the job is dynamic, 100% effective engineering controls to handle the welding fumes is really very difficult Personal Protective Equipment have limited effectiveness in reducing the likelihood and the consequence of risks and harm associated with exposure to welding fumes

4 Meth ds

Illness patterns of large number of welders deployed at various project sites were studied Based on the findings suitable engineering intervention possibilities were explored Details are given below:

1 Study n Illness pattern f welders

A study on 870 illness cases reported at medical centre at five major construction projects were analyzed and it was found that 73% of the welders have reported eye irritation followed by eye irritation as well body pain by 16% of the welders Details highlighted in Chart 11



1 Chart showing various illness related to welding

Ventilation arrangements were studied for various welding applications In outdoor or semi-outdoor situations, natural air circulation can be sufficient to provide enough ventilation Its effectiveness, however, depends on whether the day is windy or calm and in wind direction upwind or downwind Using welding curtains, spark enclosures or hoardings when working outside prevents exposure to natural air movement and therefore prevents effective ventilation[4]

5 Interventi ns:

1 General ventilati n

In indoor locations and confined spaces, draft fans or air-movers provide general or dilution ventilation A well-designed and well-maintained ventilation system is usually effective for most situations involving clean, uncoated, mild steels However, the only means of judging if the system is doing its job is to take regular airflow measurements and to sample for exposure

For example, in the USA, Occupational Safety and Health Administration (OSHA) require that a minimum of 65 cubic meters (2000 cubic feet) of air be moved per minute for each welder in a room These figures might vary if, for example, a plasma-arc machine is being used inside a room

2 L cal exhaust systems

Vent hoods or gun-mounted exhausts can provide local exhaust ventilation Local exhausts are the most effective ventilation systems for all situations that generate fumes containing heavy metals and, particularly, for stainless steel or plasma-arc welding In field locations portable hoods may be explored The effectiveness of local exhaust ventilation depends on the distance the hood is from the source of gases and fumes, on the air velocity and on the hood placement

2 Photo of a local exhaust ventilation system

3 L cal exhaust ventilati n

Hazardous atmospheric contaminants can often be controlled effectively at their source by means of a local exhaust system This system comprises:

a. a hood which captures the contaminant at its point of generation;

b. a duct system with appropriate airflow;

c. an air cleaning system to prevent pollution of the general atmosphere;

d. Figure: 20

e. a stack or other means of dispersing the decontaminated air into the atmosphere

6 Results

Reduction of harm potential is achieved through reduction of concentration of hazardous fumes/ gases in the breathing zone of the operator Accordingly, concentrations of relevant common hazardous fumes/gases are measured in before and after the intervention

As per hierarchy of controls, engineering control is one of the effective options after elimination and substitution However additional controls such as regular medical examination of welders, regular supervision / surveillance of welding operation is also very important aspect of consideration for an effective and safe welding operation

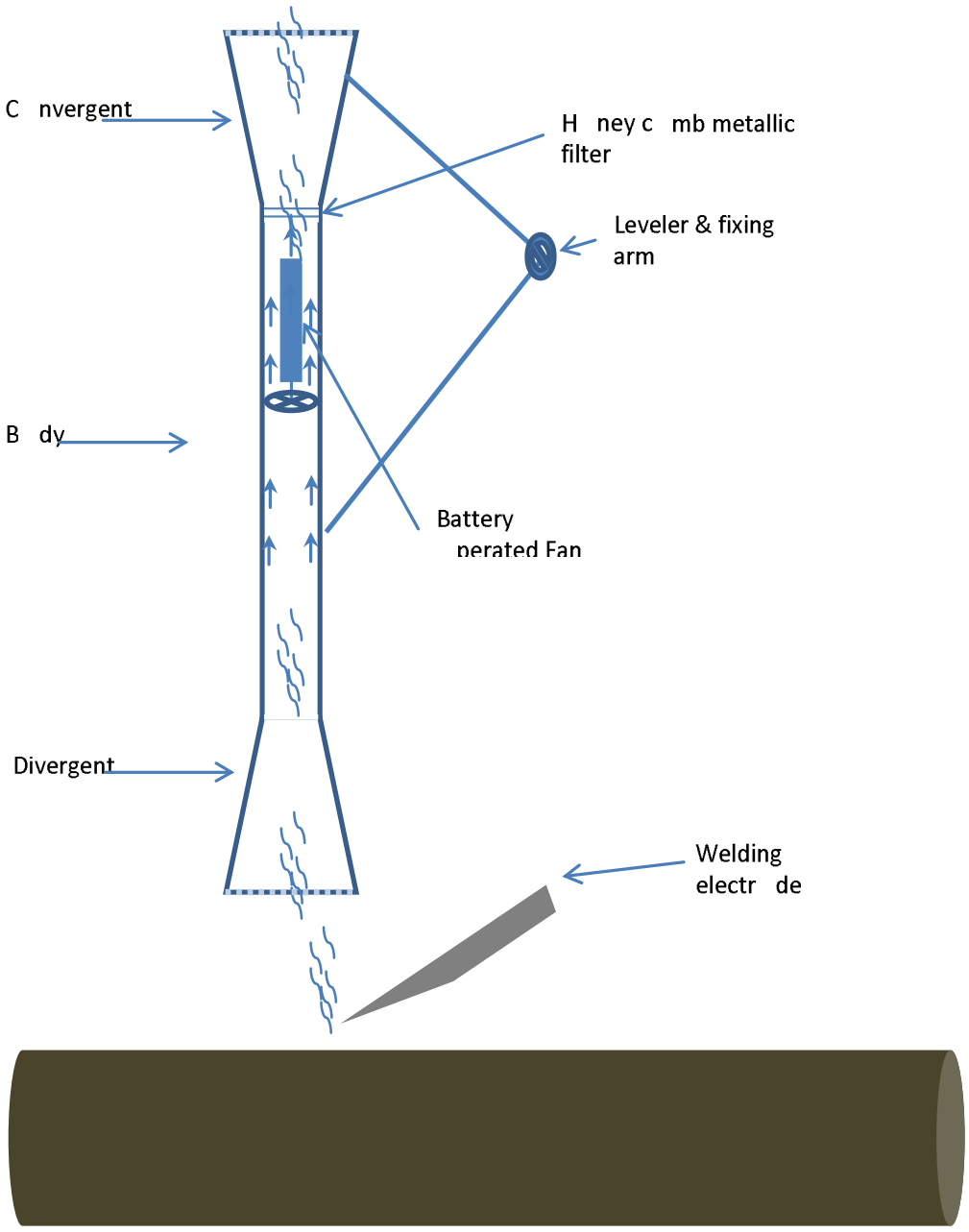
A simple, easy-to-fix, forced ventilation equipment to handle welding fumes was fabricated This equipment can easily be fixed at various typical work-spots based on the specific requirements The new ventilation system has the following components:

- Divergent Portion: The place through which the welding fumes are taken inward through the battery operated fan fixed inside the body of the equipment
- Body: It is the central portion through which fumes are transferred to the filtration process; the filter is generally a honey comb metallic filter
- Filter: This is simple metallic honey comb structured metallic filter This will facilitate the filtration process of welding fumes
- Convergent: The convergent portion enables venting of welding fumes that are generated from the filtration process
- Leveler & fixing arm: The ventilation system has a leveler and a fixed arm, the leveler arm helps in projecting the divergent portion towards the welding fumes and fixing arm helps in fixing the same to the any structure Hence this arm enables the quick fix arrangements

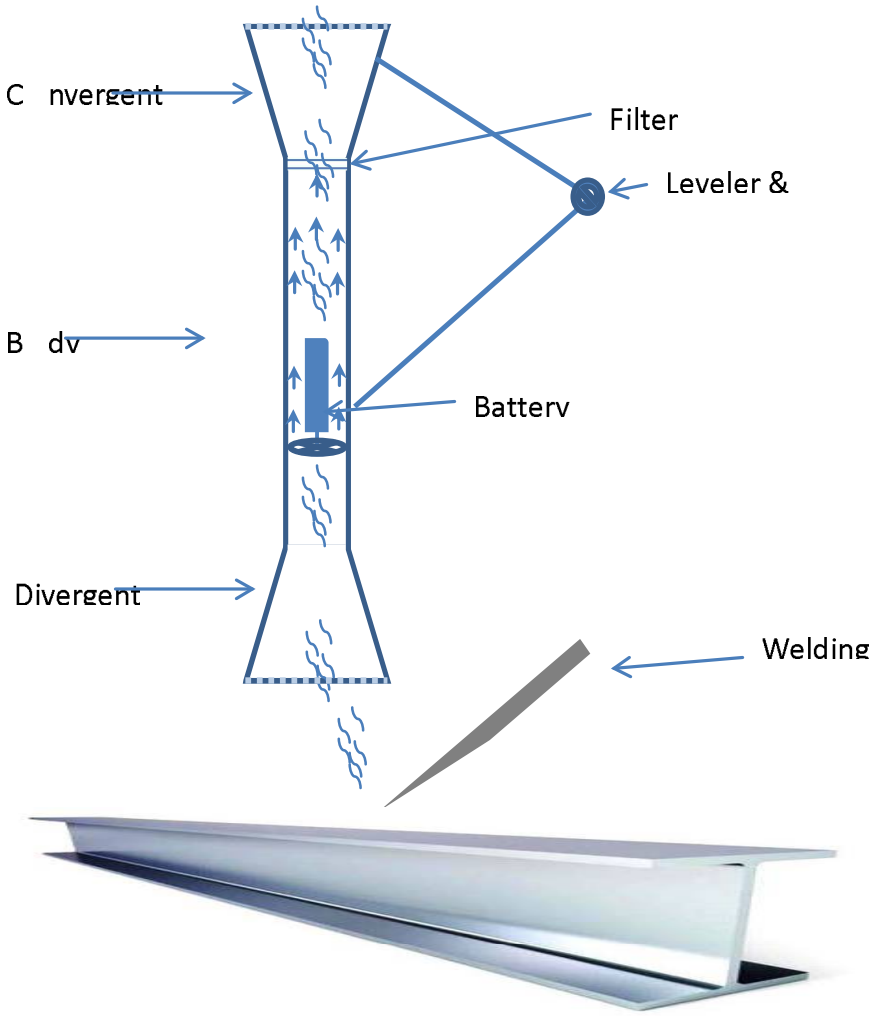
The new ventilation system helps in handling welding fumes that get generated and removed from workplace Since filtration is a part of the ventilation process, generated welding fumes get filtered before emanating to atmosphere

The applications of the ventilations systems are being utilized for various types of applications as given below:

- Ventilation system for welding pipes
- Ventilation system for welding structural steel
- Ventilation system inside confined space (Inside Pipes, Equipment etc)



3 Ventilation System for Welding Pipes



4 Ventilation System for Structural Steel

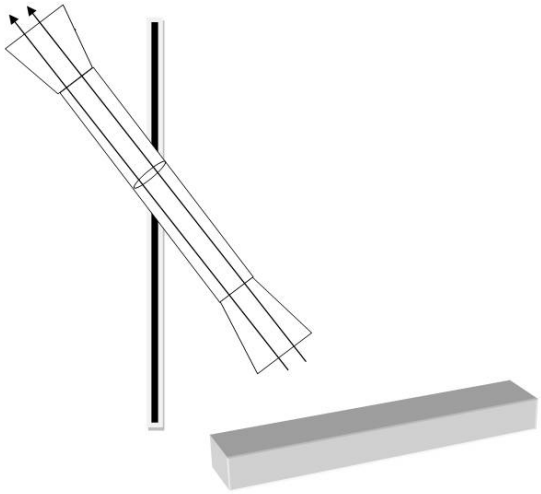
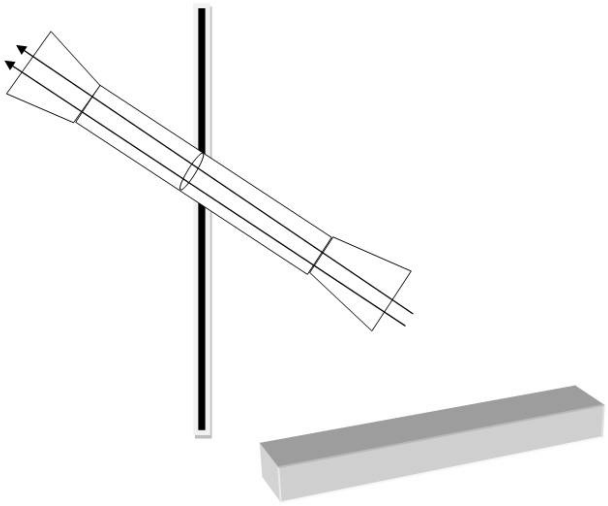


Figure 6.5 a



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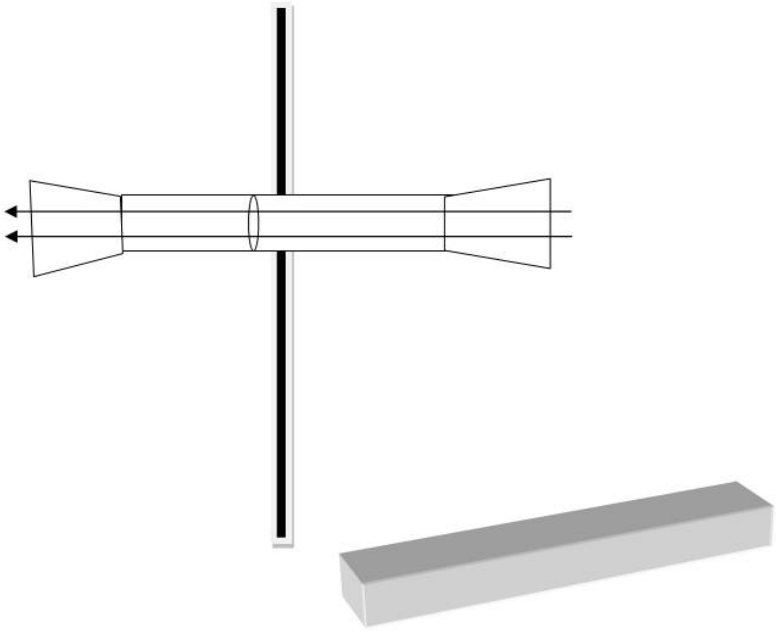

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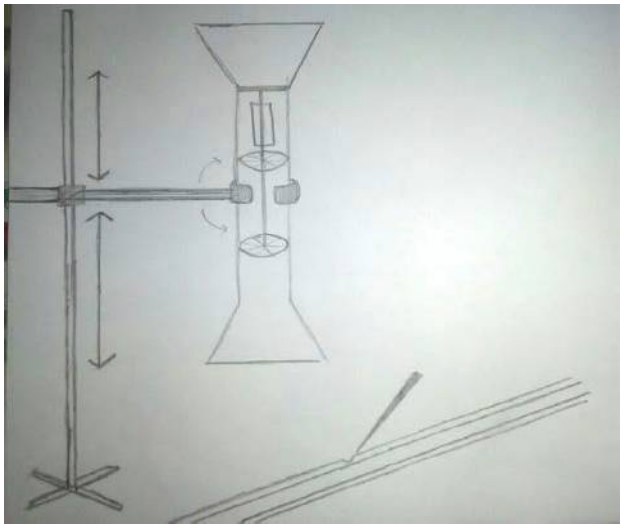
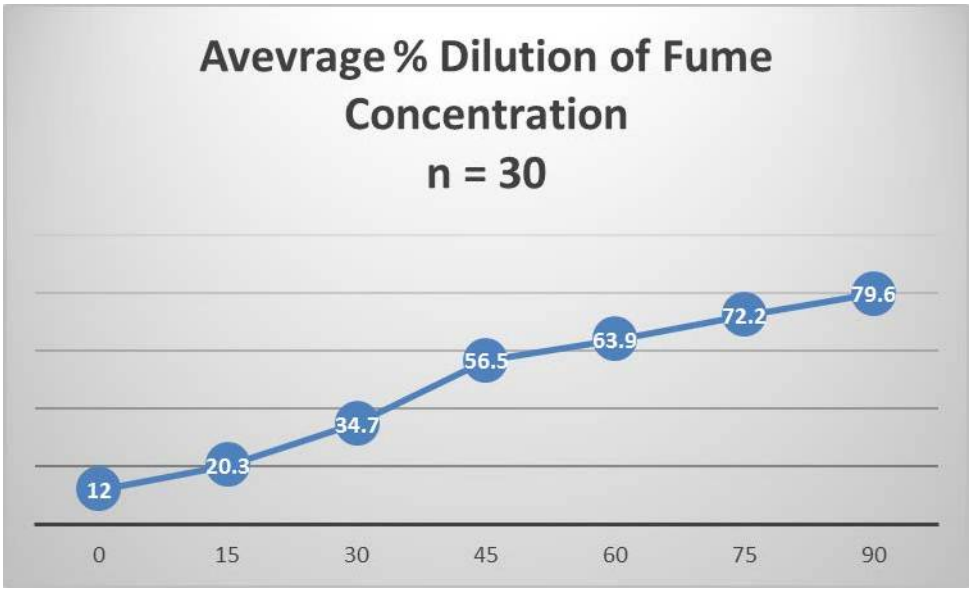


Figure 6.5 d

Figure 5 Schematic diagram of Ventilation System

Variation of average percentage of dilution of fume concentration at various angles of the portable head

Angle f the P rtable H d (degree) with h riz ntal	Average % Diluti n f Fume C ncentrati n n = 30
0	12
15	3
30	7
45	5
60	9
75	2
90	6



6 Analysis of effectiveness at various angles

7 Findings

Reduction of harm potential is achieved through reduction of concentration of hazardous fumes/ gases in the breathing zone of the operator Accordingly, concentrations of relevant common hazardous fumes/gases are measured in before and after the intervention

5 Concentration of common hazardous fumes/gases and their safe concentration limits

n = 30					
Descripti n	**Bef re**	**After**	**Safe C ncentrati n Limits as per Schedule XII f B CW Central Rules**		**Test meth d**
			PPM	**mg / m^3**	
Carbon Monoxide	325 PPM	9 PPM	50	-	Instrumental Analyzer Procedure
Lead & certain inorganic compounds	015 mg / m^3	010 mg / m^3	-	015	Flame or electrothermal atomic absorption pectrometry
Oxides of Nitrogen	20 PPM	12 PPM	25	-	Chemiluminescent Method
Cadmium or its compounds	005 mg / m^3	003 mg / m	-	005	AES - Inductively coupled plasma atomic emission spectroscopy;

8 Discussi n

Implementation of the above-mentioned engineering control measures are effective for reducing the concentration of harmful substance at the breathing zone of workers exposed during manual metal arc welding process at construction sites