

L7 : ENVIRONMENTAL LEGISLATION AND POLLUTION CONTROL IN CAST IRON FOUNDRIES

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INTRODUCTION

It is a time-old relationship between metal and man : iron is one such metal in use. To meet various needs, iron is melted and cast into the desired shapes; this phenomena has brought into the very existence of Cast Iron Foundries. To melt iron, energy in the form of heat is provided through combustion of carbon, the most techno-economic form of which is coke. Besides heat, the other products of this combustion, fine particulates of ash, CO, SO_x, NO_x etc. are released to the atmosphere. In a small area, such as Howrah, about one million ton of CI Castings are made annually burning 300,000 tons of coke of which ash constitutes one third of its weight. In the process, the ash gets converted partly into slag and remaining find its place in the atmosphere in the form of solid particulate matter causing environmental problem for the people and living objects in the vicinity of these foundries. The cumulative effect of this practice for years has caused an alarming situation compelling us to find out urgently most conducive solution.

This problem is world-wide and has been considered by the guardians of different Nations and various Environmental Preventive Acts (EPA) have been formulated to prevent indiscriminate release of harmful materials to the environment. All such efforts in the developed world has resulted better environmental conditions; but simultaneously boosted up the cost of their products due to adoption of suitable pollution abatement measures. According to Mr. Nick Thurston, Principal Pollution Control Officer,

Walsall Borough Council, U.K. it would be prohibitively expensive for small cold blast cupolas of below 4 tons per hour output to maintain emission level as prescribed in EPA-90.

Our country is also not lagging much behind. Already Central Pollution Control Board (CPCB) at Delhi through different State Agencies is seriously looking at this problem since some time; legislations have been made and some are in the process. State authorities are advised to be vigilant and strictures are coming from the Supreme Court. To overcome this state of affairs, it is high time to take an account of this problem under Indian scenario and to find out some techno-economic solutions for the foundries.

SOURCES OF POLLUTANTS IN CAST IRON FOUNDRIES

Depending on the character and size of the foundry, emission of pollutants takes place. In a cast iron foundry the areas of emission may be broadly classified as follows :

- (i) Emission from the melting pot : Cupola
- (ii) Emission from non-melting areas : raw material storage spaces, sand preparation, mixing, moulding, core making, shake-out, cleaning etc.
- (iii) Emission from hot chamber

The schematic diagram of a typical CI Foundry (Fig. 1) illustrate the above.

Emission from cupola

Cupola is a traditional melting pot in a cast iron (CI) foundry. It has got a unique character to achieve the target at a minimum investment and operational cost. Coke is the basic fuel to provide necessary thermal energy to get the solid metallic charge melted and raised to a desired temperature for proper casting. Coke, particularly of Indian origin, contains a very high ash percentage. At Howrah mostly beehive coke is used. Here not only high ash content (35-40%) is a troublesome phenomenon but also inherent volatile matters cause certain additional problems. To take care of the ash content of coke, appropriate quantity of fluxing material like limestone is added to the charge to get the slag in proper fluid state. Fig-2 illustrates the mechanism of the role played by ash during combustion of coke. In the presence of adequate fluxing material, 1440°C is the softening temperature of ash. Subsequent to the burning of coke in presence of oxygen available in air, the released ash gets converted into slag above the temperature level of 1440°C with the help of fluxing material like lime-stone, or solid particulate matters (SPM) below the temperature level of 1440°C . Slag thus produced in molten condition is drained out through the slag-spout while the SPM produced gets drifted upward alongwith the air-current through the stack and finally escapes to the atmosphere through the tip of the furnace. The size of this particulates being of the order of a few microns, remain suspended in the air and cause adverse effect to the environment.

Sulphur content in coke gets oxidised as combustion takes place and the product, SO_2 and SO_x joins the exhaust gas through the chimney. However, as it has been observed that 50% of sulphur from coke gets absorbed by the metal and most of the remaining get oxidised and go out alongwith the exhaust gas, only a small portion goes to the slag.

At the combustion zone of the cupola, carbon from coke is converted mostly into carbon-dioxide and move upwards through the stack region. In the process a part of it gets reacted with incoming charge coke liberating carbon monoxide. This carbon monoxide alongwith unreacted carbon-dioxide escapes the cupolas exhaust gas. Similarly Nitrogen-oxides, if produced, also escapes alongwith the exhaust gas.

Emissions from Non-melting operational area

Non melting operations in a cast iron foundry include raw material handling, pattern making, sand mixing, mould and core making, pouring, shake-out and fettling, etc. During these operations the major pollutants emitted are shown in Table-1.

Table-1 : Major pollutants in non-melting areas of a C.I. Foundry

Sl.No.	Operational area	Pollutants
1.	Raw material handling and storage	Dust
2.	Pattern shop	Saw-dust and wood chips
3.	Sand preparation and mixing	Dust
4.	Mould and core making	Dust and CO
5.	Pouring	Slag
6.	Casting bay	Dust and CO
7.	Shake out and fettling	Dust

Most of the dust particles emitted in these areas being larger in size gets settled in nearby areas, however, to protect the workers from being exposed to these pollutants suitable masks are to be used.

Emission from Hot Chamber

All C.I. foundries are having hot-chambers of suitable size to dry cores and moulds. These chambers are mostly heated by passing stream of hot air evolved from burning coal. Depending on the design of the coal-burning system pollutants like CO, CO₂, SO₂ and smoke are emitted.

LEGISLATION

In order to assess the extent of pollution in any area or at the vicinity of any process plant, the first requirement is to design a standard against which a pollution source should be compared. Around the world many such standards have been designed to data keeping in view of the nature of industries a country has and other relevant conditions applicable to that country. It may be noted that even through these standards vary to some extent, there are lot of similarities among them. Some of these standards have been designed by such agencies as United States Environmental Protection Agency (USEPA), standards designed by British Standard Institution, National Society for clean air (U.K), and in India Central Pollution Control Board and the respective Pollution Control Boards of each state, West Bengal Pollution Control Board, in the present context.

As a typical example Table-2 gives the national ambient air quality standards adopted by the united States EPA. Similarly the British Standards BS 1747:19 provides the methods of measurement of air pollution. Similarly in India Central Pollution Control Board publication "Pollution Control Act, Rules and notifications issued therein", published in December 1992 provides major guidelines with respect to the assessment and center of pollution from different industries.

In similar lines for example West Bengal Pollution Central Board has developed its own guidelines. The limits of emission for cupolas as designed by

West Bengal Pollution Control Board is given in Table-3. It may be noted that the CPCB designed separate norms for suspended particulate matters for different sizes of cupola are different. On the contrary the British Standard specifies the uniform emission limit of $\sim 115 \text{ mg/Nm}^3$ for cupolas for all sizes. Since there is no scientific logic for fixing different standards for different sizes of cupola based on melting rate (not dia of cupola), this point requires to be critically looked into. Another point that needs careful consideration is the most appropriate sampling point. In some cases the sampling done at the charging door and not at the stack exit. The character of stack air near charging door is not necessarily be the same as it is released to the atmosphere from the system. Hence it should be more appropriate to do the sampling at the stack exit. Further, this allows sampling at any point of time during the operation, and it is sensitive to changes in stack height.

CONTROL MEASURES

It is evident from the present practices, the emission released from C.I. foundries of India in general and of Howrah in particular are much above the desired level as prescribed by the Pollution Control authorities in India. This has compelled the concerned industries for their survival to look around for some acceptable solutions. Cupola being the main source of emission violating the pollution norms, require special attention.

The study reveals that liberation level of SPM and SO_x are causing problems ; other pollutants like CO and NO_x are not in an alarming state. The common source of all these pollutants is the process of coke combustion to meet heat demand of the furnace i.e. cupola. Hence, more efficient is the combustion process less is the requirement of coke resulting less evolution of pollutants. Thus the pollution problem from cupola is to be dealt with in two stages - (i) Making the cupola more fuel efficient, and (ii) arresting the pollutants before the exhaust air is allowed to be released to the atmosphere.

1. Fuel Efficient Cupola Operation

Most of the cupolas in Howrah do not satisfy the engineering needs of dimensional proportions resulting in poor heat exchange, incomplete combustion, etc. The following aspects are to be considered for remodeling the cupola to make it a fuel efficient one :

(i) Design Parameters :

Fig-3 presents line diagram of a typical cupola outlay in Howrah foundries. Air is one of the most important component for combustion, its availability both in adequate volume and pressure in the combustion zone is essential for efficiency purpose. If the volume and/or pressure is more or less than the actual requirement, it will effect the efficiency. This phenomenon invites a thorough check in the entire system covering capacity of the blower, air transporting, distribution through wind-belt and tuyere system and finally the ratio between tuyere openings and area of combustion. Keeping in mind about fuel efficiency, number of methodologies have been suggested for adoption like divided blast, equi-blast, balanced blast etc. In each case the conventional design to wind belt and its distribution system is to be modified suitably. Before selecting any, points relating to intending practice, ease of operation, financial commitments, etc. are to be considered. Once this aspect is settled, the tuyere openings in the cupola are to be suitably adjusted. It is a common practice to have sets of tuyeres at two different levels having some space in between, this space is to be maintained in view of widening of the combustion zone. Since combustion of coke affects considerably with the ratio between tuyere-opening area and cross-sectional area of the dia. of the cupola, this factor is essential to be ascertained appropriately.

After combustion, the gaseous products travel upwards confronting with the down coming solid charges, this area is normally termed as stack region and

extends between charging door level to the melting zone. Here adequate heat exchange should take place between the hot outgoing gases and the cold incoming charges to pickup sufficient temperature before it reaches the melting zone. Simultaneously CO_2 , the main product of coke combustion during its travel through the stack region comes in contact with the charge coke; depending on reactivity of the coke, gets partly converted into CO through an endothermic reaction. So considering these two opposing consequences, it has been accepted that the stack height should extend 5 to 6 times that of the cupola inner dia.

The portion above the charging door functions as chimney to give an easy passage for the exhaust gases. This portion, according to the norms laid down by the pollution authorities is to be extended 6 times that of the dia. of the chimney.

(ii) Operational Practices

There are certain areas of apparently less importance where mere ignorance causes high coke consumption. Cupola charges is one such area. Very little attention is paid to the material size of coke and metallic charges. It has been observed that metallic pieces weighing 60-80- Kgs are charged in a cupola having inner diameter of the range of 36" to 40". Such incidences reduces the metallic flow rate within the furnace due to obstructions created at the melting zone. Similarly the charge coke of below 2" size becomes relatively more reactive due to their surface area compared to their mass; this helps to increase the possibilities of more endothermic reactions between the outgoing CO_2 and incoming carbon yielding CO. To overcome these problems, it has been prescribed to (a) reduce the size of metallic charges before charging to the tune of 1/8th to 1/12th of the I.D. of cupola, and (b) to remove the coke pieces smaller than 2" in dia.

(iii) Instrumentation

Practically all the Howrah foundries are not having any instrumental facilities to assess the entire process control system. Even the rudimentary weighing scales are absent in some of the charging platforms; the charges are generally estimated by number of bucket full materials charged. Most of the foundries are not having any equipment to ascertain the volume of air getting into the furnace and its pressure is almost unknown to the cupola operators. All these induce a sort of uncertainty about the combustion and heat flow taking place within the furnace.

It is a bare necessity to be equipped with the instruments to provide data on volume and pressure of the air going in, temperature of the molten metal coming out, the actual weight of each charging materials going into in every batch, as also a fair idea of the chemical analysis of the charging material.

All the points discussed above are to be taken into consideration as a positive step for making a cupola fuel efficient, in other words, consumption of coke minimised in terms of molten metal output of a cupola.

2. Pollution Abatement

Once emission has set in and the exhaust gas is contaminated with SPM, SO_2 and CO at a level much higher than the prescribed limits of Pollution Control Authorities, some measures to arrest the pollutants are essential.

Depending upon the sizes of the particulates and their weight distribution in the exhaust gas, a separating device or combination of devices may be selected for use. In case of wide size distribution of particles, it is desirable to separate coarser particles first involving equipment requiring low capital and operating cost. This also avoids unnecessary loading of

high-efficiency units capable of separating smaller sizes efficiently. Hence, one has to choose, select and specify equipments according to the separation work required. The quantity of gases to be handled and their dust loads are other important factors in the selection of equipment. Flow velocities determine the pressure loss through the equipment. It is desirable that flow velocities are kept low by a proper choice of equipment. The value of the separated solids and required efficiency of their separation are sometimes important considerations in the selection of equipment.

There is a wide list of separating devices working on principles for arresting pollutants such as (i) gravitation, (ii) centrifugal force, (iii) internal impaction, (iv) direct interaction, (v) diffusion, (vi) electro-static force, and (vii) filtration. Following are commonly used collectors :

Dry/Wet arrests :

The simplest method of arresting grits is to attach a dry or wet arrester to the cupola top. Since all the gases are drawn through the arrester by stack draught alone, enough height and diameter should be provided to make the arrester large enough to pass all the gases and air infiltrated through the charging door. Dry arresters are usually refractory lined with the core unlined while the wet arresters are unlined and capable of removing dust particles to the extent of 50%.

Cyclone type centrifugal collectors

Cyclone separators make use of centrifugal forces for arresting the particles. In general, it consists of a cylindrical and a conical portion (Fig.4) with a rectangular tangential entry. As the gas enters, it spirals downwards in an outer vortex and comes out of the unit in an inner vortex. During its stay in the unit the gas makes a given number of effective turns which is

related to the efficiency expected. Cyclone separators are generally employed for separations following well accepted configurations depending on the volume of the gas to be handled and the particle-separation efficiency required.

The most striking aspect of cyclone separators is that they have no moving parts. This makes them highly reliable, simple to construct and least expensive of all high efficiency particle separators.

Wet CAP Collector/Low pressure scrubbers

In liquid scrubbers, the exhaust gas is brought in contact with a fine spray of liquid, usually water. The separation of particles occurs essentially by impaction, interception and diffusion, through humidification, condensation, wetting and gravitation, all these phenomenon have their role to play. There are a large variety of wet collectors that have been commercialised. Spray towers, packed towers, impingement scrubbers, cyclonic scrubbers and floating-bed scrubbers are low energy units (Fig-5). The pressure loss is between 2 and 15 cm of water but the efficiency of collection for low particle size is limited. Particle size above 5 microns can be easily removed.

High pressure venturi type scrubber

Fig-6 illustrates a typical dust-scrubber system using a high energy venturi scrubber. All wet collectors have a fractional efficiency characteristics; that is, their cleaning efficiency varies directly with the size of particle being collected. In general, high efficiency collection of fine particles require increased energy input, which will be reflected in higher collection pressure loss. With the development of the high-energy venturi type collector, it has become possible to collect submicron particulates, fumes and smoke with high efficiency.

Baghouse filter system

The most of versatile equipment for removal of solid particulates from the exhaust gas is the fabric dust collector (Fig-7). With a mass medium size of 0.5micron, a collection efficiency of virtually 100 percent can be expected. As the filter media becomes dirty in a fabric collector, the higher the efficiency of the unit becomes, and the finer the particles removed.

Filter media are now available for hot corrosive atmosphere such as cupola emission yet the exhaust gas from cupola is always preferred to be cooled down before allowing them to enter the bag-house filter system. However, the cost of introduction of this system as also its operational cost is very high and should be accounted for ascertaining the cost-benefit analysis.

Electrostatic precipitators

Electrostatic precipitators work on the principle of charging the solid particles suspended in air or gases by means of gas ions or electrons produced by ionization of gases under a high energy electric field and subsequent separation under the action of the field. Electrostatic precipitators have a number of advantages over other separators. They are quite flexible in operation with regard to gas-flow and dust loading variations. The pressure-drop of gases in the unit is low and the efficiency very high (average 98 to 99 percent), even for small particle size as low as 0.05 microns. The units can work upto gas temperature of 350°C, in SO₂ and moist atmospheres. They have a lower operating cost as compared to other high efficiency gas-cleaning equipments. The cost of precipitators increases for electrically-resistant particles. The chief disadvantage, however, is the high initial capital cost.

SO₂ removal from exhaust gases

Sulphur-dioxide originates from the combustion of coke and its presence in exhaust gas creates some untoward situation specially if the cupola is located within or close proximity of some sensitive areas. Wet scrubbing facilitates physical absorption of SO₂ or a chemical reaction. The absorbent should be able to absorb SO₂ at a fast rate so as to reduce the size of the equipment. Besides, it should be possible to regenerate the absorbent to make the process viable in practice. SO₂ being slightly soluble in water, its use as an absorbent is ruled out. However, low pressure steam, if available, can be employed for stripping SO₂. In actual practice a chemical reaction is incorporated since mass transfer with chemical reaction enhance the rate of absorption.

Sulphur dioxide being acidic in nature, is readily absorbed by alkaline solutions. There are a number of scrubbing solutions like (i) Lime/limestone solution/slurries, (ii) MgO slurries/Mg(OH)₂ solution, (iii) NaOH solution, (iv) Na₂ SO₃-NaHSO₃ solution, (v) Na₂ CO₃ solution, (vi) NH₃ liquor solution, (vii) Dimethylaniline solvent, (viii) Xylidine-water system and (ix) Ammonium sulphate solution. The first three of the above are very much common in practice; Fig.8 illustrates these presses.

The economics of the process selected depends on the availability of raw materials and market for the by-products such as sulphur, ammonium sulphate, calcium sulphate etc. formed. The capital cost is least for lime scrubbing and most for MgO scrubbing. The operating cost is least in the case of ammonia scrubbing, as the by-product ammonium sulphate has good marketability.

FUTURISTIC APPROACHES

During the recent past considerable work has been done resulting in new developments. Cokeless cupolas are now well established. Further modifications have been successfully tried to a combination of coke and oil firing to obtain flexibility in melting rate and very low smoke and carbon monoxide emission. New fuel systems ensure low particulate emissions controlled by small and very efficient cleaning units.

In the developed world cupola melting for C.I. castings are slowly being eliminated due to various reasons out of which high labour cost and stringent pollution control acts are very predominant. Control of pollution has been a big factor in switching over to electric furnaces. Energy taxes on power, changes in pricing structures, quality and availability of scrap have generated new interest in lean fuel process which may turn out to be as clean as electric melting and more efficient. This is a significant challenge, which will win or lose is by no means certain.

CONCLUSION

The sources of emission of pollutants from cast iron foundries have been discussed in this paper. The sources have been classified in two major categories viz. melting area and non-melting area. The pollution problem of the melting zone i.e. cupola being enormous has been dealt with in detail and abatement measures were suggested in two ways, one by making the cupola, fuel efficient by incorporating design and operational changes, and the other, by arresting the pollutants from the exhaust gases before releasing to the atmosphere. Different devices for pollution control were also discussed. The legislation already formulated by the Indian authorities were focussed.

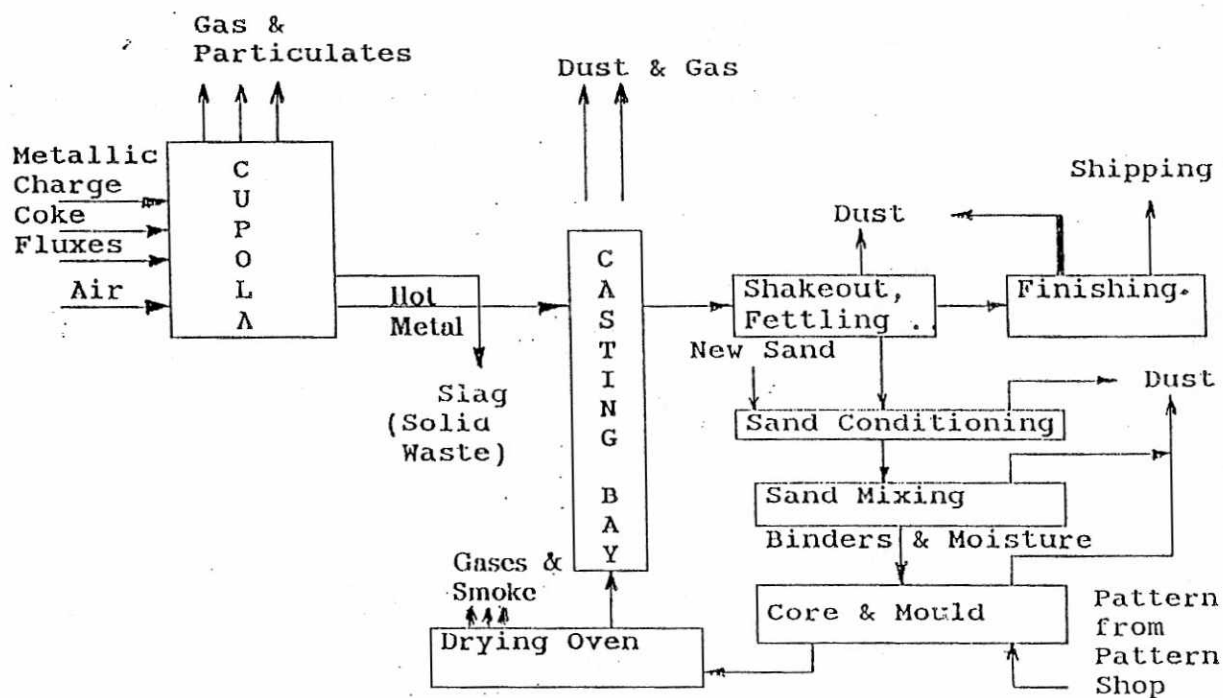


Figure 1. Detailed sources of dust emissions from cast iron foundries

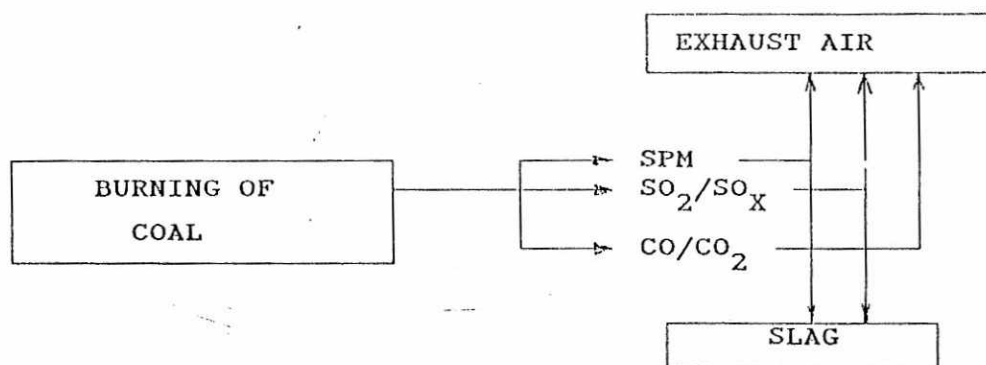


Figure 2. Schematic diagram of sources of pollution from burning of coal

TABLE - 2

National Primary and Secondary Ambient Air Quality Standards (USEPA)

Pollutant	Type of standard	Averaging time	Frequency parameter	Concentration	
				$\mu\text{g}/\text{m}^3$	ppm
Carbon monoxide	Primary and secondary	1 hr	Annual maximum	40,000	35
		8 hr	Annual maximum	10,000	9
Hydrocarbons (nonmethane)	Primary and secondary	3 hr (6 to 9 a.m.)	Annual maximum	160	0.24
Nitrogen dioxide	Primary and secondary	1 Yr.	Arithmetic mean	100	0.05
Photochemical oxidants	Primary and secondary	1 hr	Annual maximum	160	0.08
Particulate matter	Primary	24 hr	Annual maximum	260	—
		24 hr	Annual geometric mean	75	—
	Secondary	24 hr	Annual maximum	150	—
		24 hr	Annual geometric mean	60	—
Sulfur dioxide	Primary	24 hr	Annual maximum	365	0.14
		1 Yr.	Arithmetic mean	80	0.03
	Secondary	3 hr	Annual maximum	1,300	0.5

TABLE - 3

LIMITS OF EMISSION

a) As specified by West Bengal Pollution Control Board

from cupola	:	SPM	:	400	mg/NM^3
		SO ₂	:	1200	mg/NM^3
		CO	:	250	mg/NM^3

from Hot Room	:	SPM	:	250	mg/NM^3
		SO ₂	:	1200	mg/NM^3
		CO	:	250	mg/NM^3

b) As specified by Central Pollution Control Board

from Cupola of

i)	3 T/hr or higher	:	SPM	:	150	mg/NM^3
ii)	Less than 3 T/hr	:	SPM	:	450	mg/NM^3

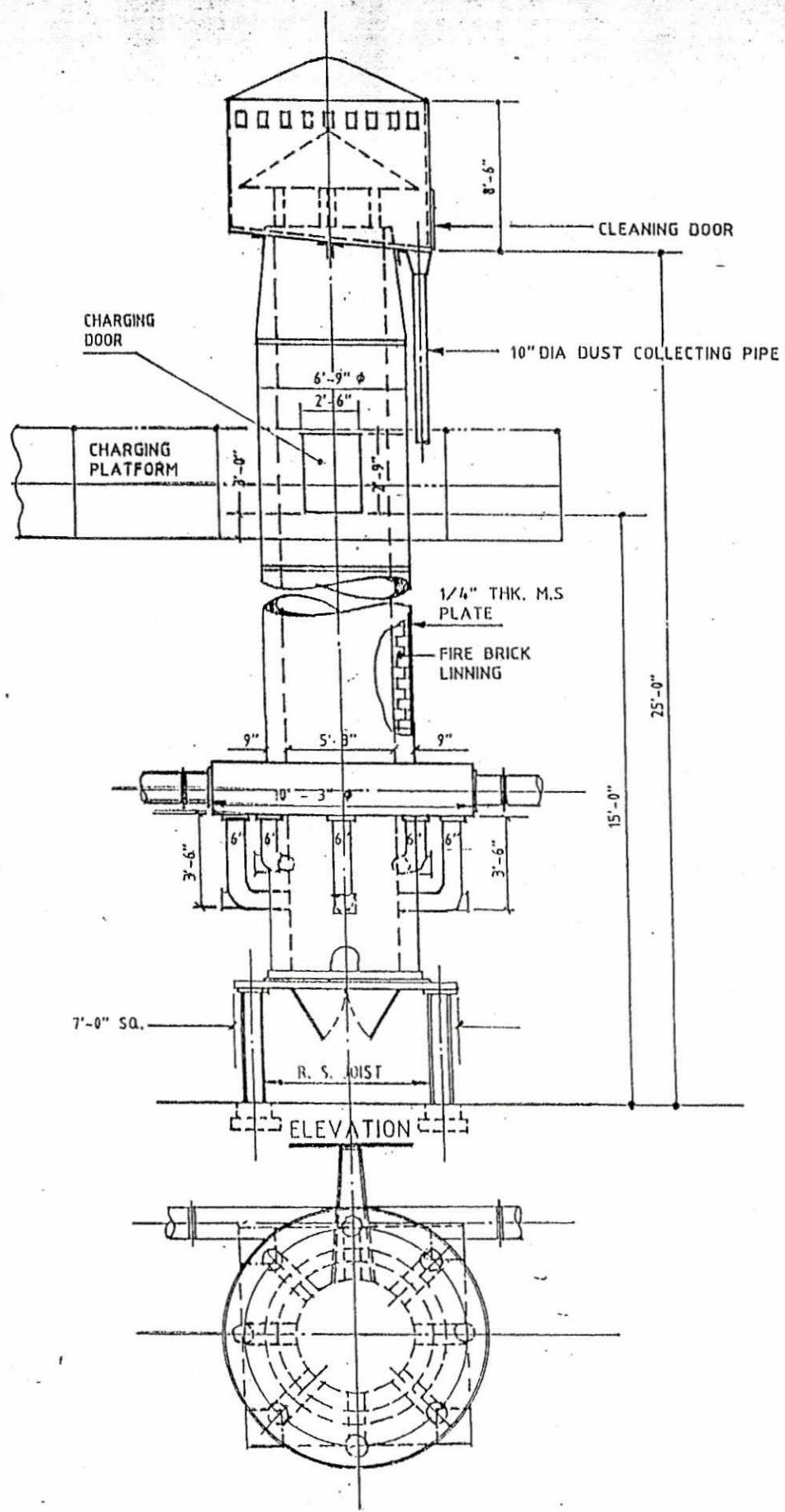


Fig.3 PLAN OF TYPICAL HOWRAH FOUNDRY CUPOLA

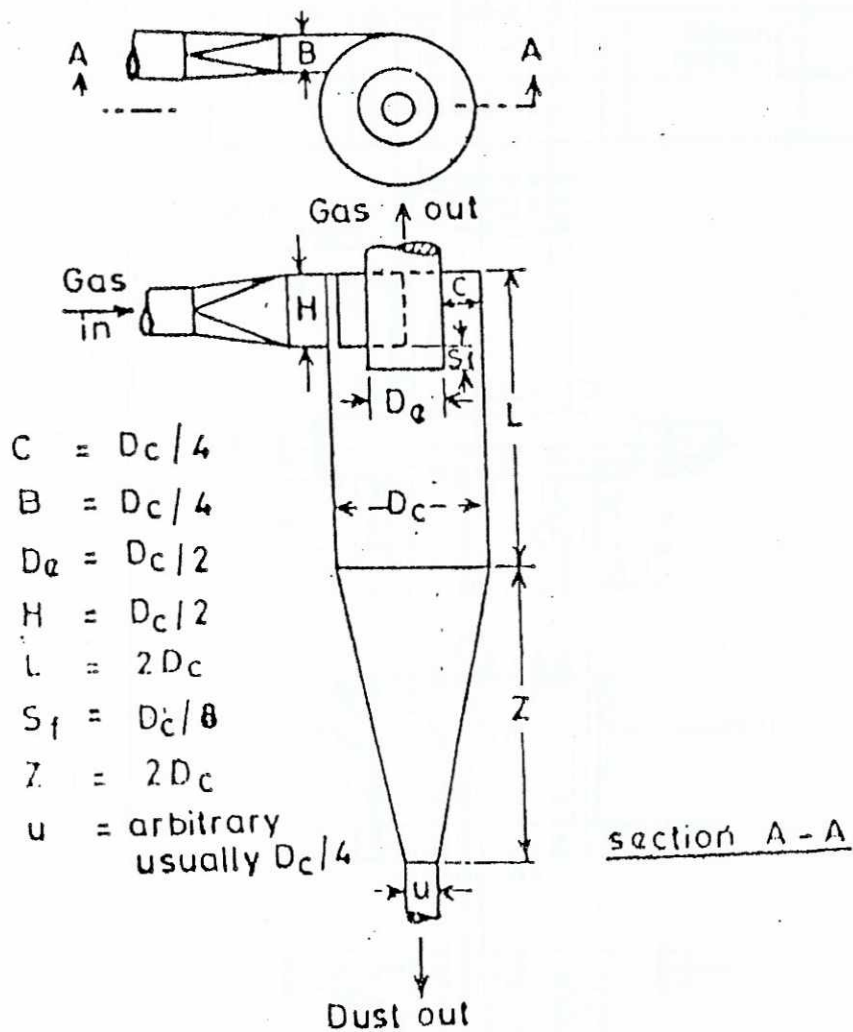


Fig. 4 Cyclone separator for a given standard configuration

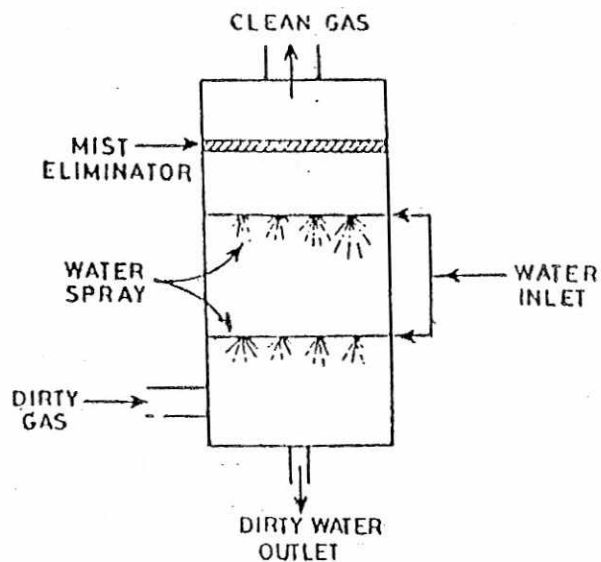


Fig 5a Counter current gravity scrubber with a mist eliminator at top

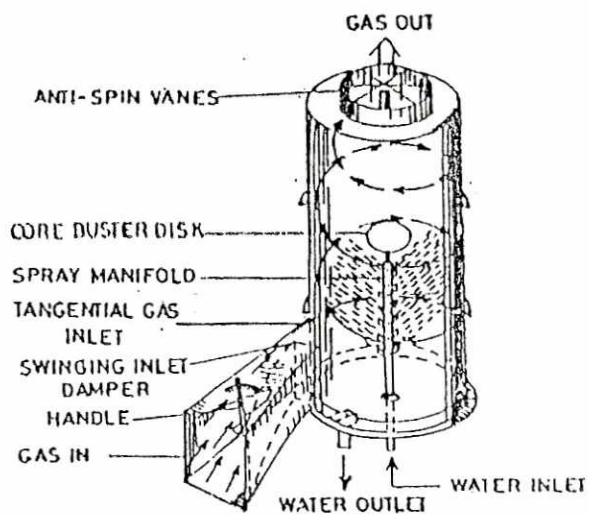


Fig 5b Cyclonic scrubber
[Adapted from Perry, op. cit., p. 1036 (1973)]

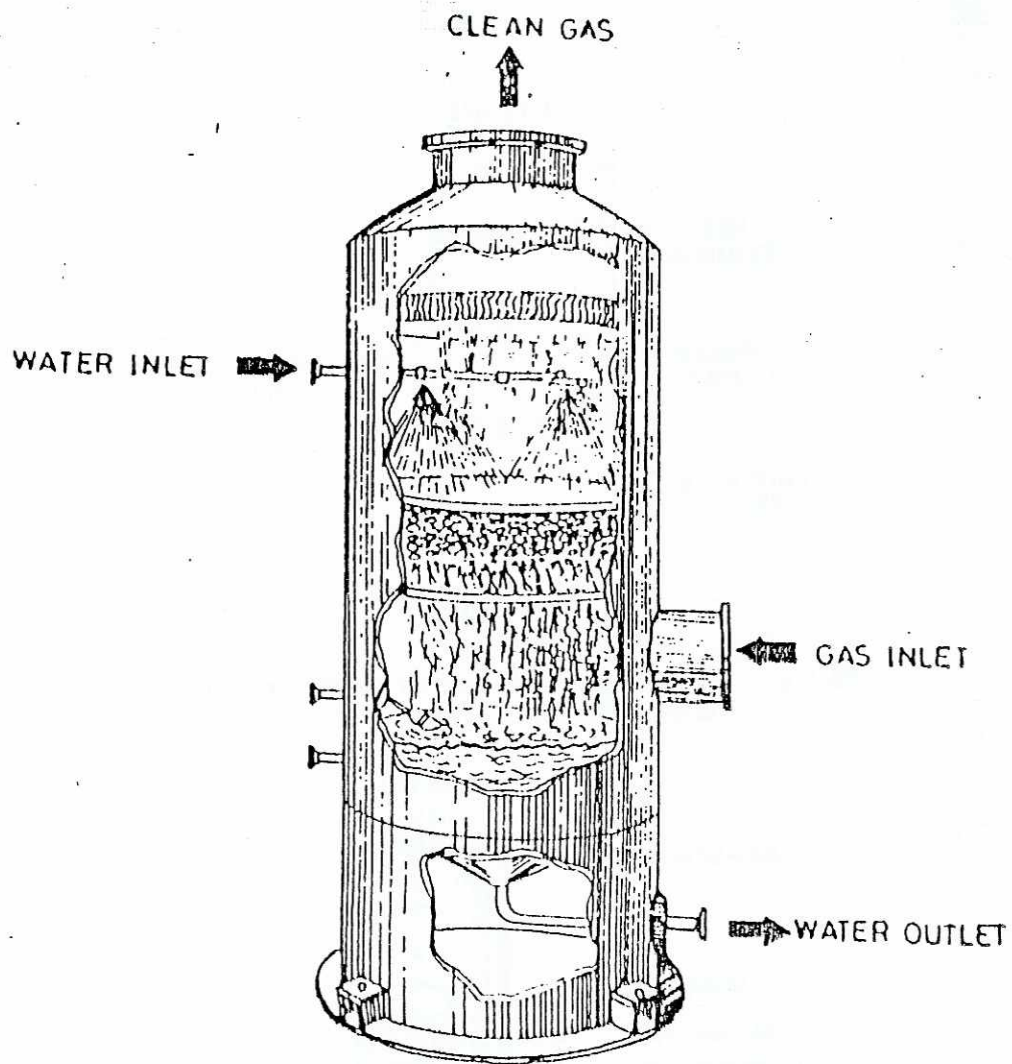


Fig 5c Floating-bed scrubber

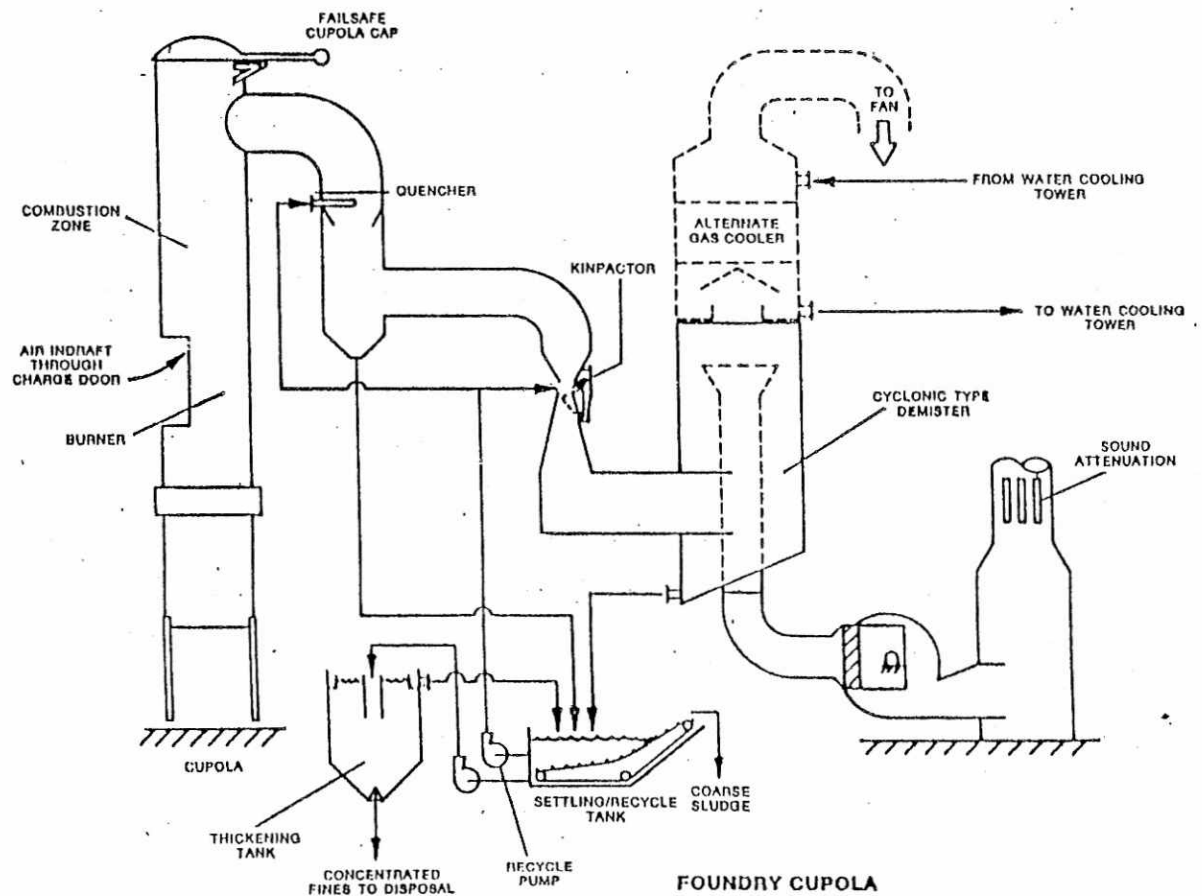


Fig. 6 High pressure venturi type wet scrubber.

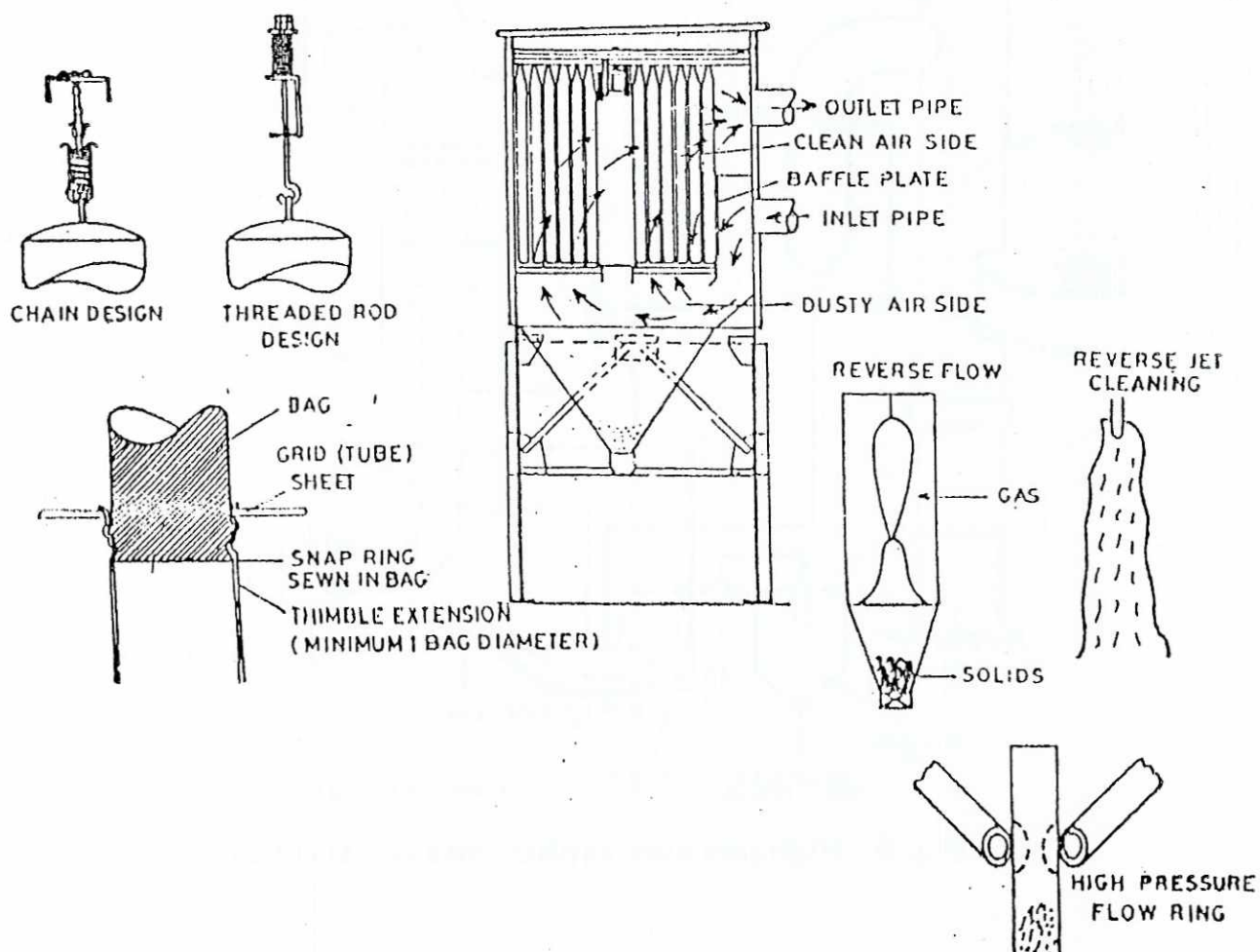
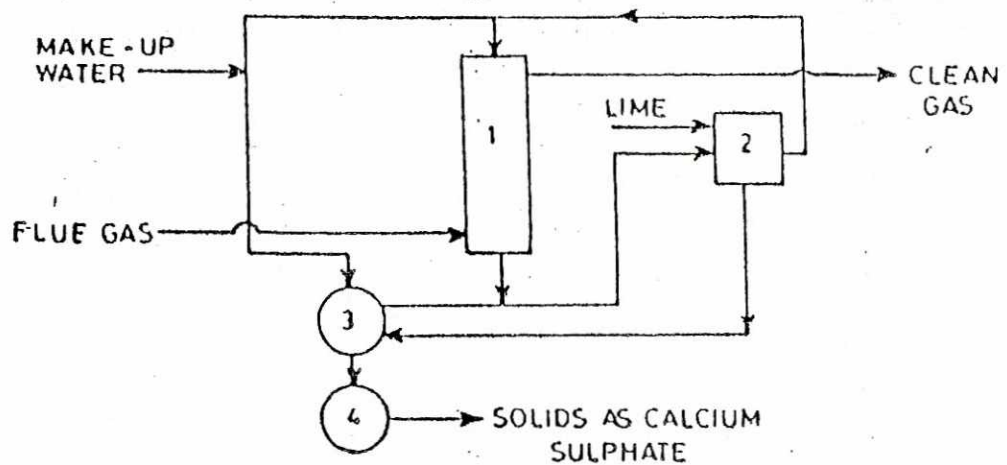
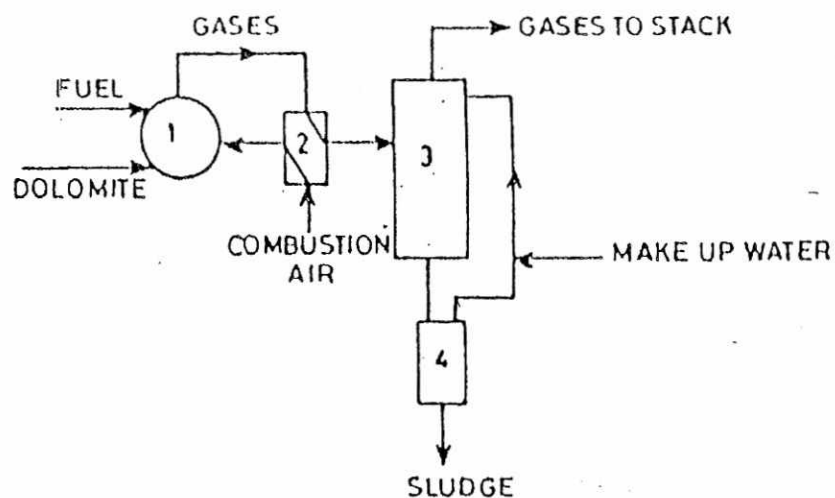


Fig. 7 Typical bag-house unit, methods of cleaning and hanger and thimble designs



(1) SCRUBBER (2) DELAY TANK
(3) SETTLER (4) ROTARY FILTER

Fig. 8a Typical lime-scrubbing process for SO_2 removal from effluent gases



(1) BOILER (2) AIR HEAT EXCHANGER
(3) SCRUBBER (4) SETTLING UNIT

Fig. 8b Dolomite-injection process for SO_2 removal from effluent gases

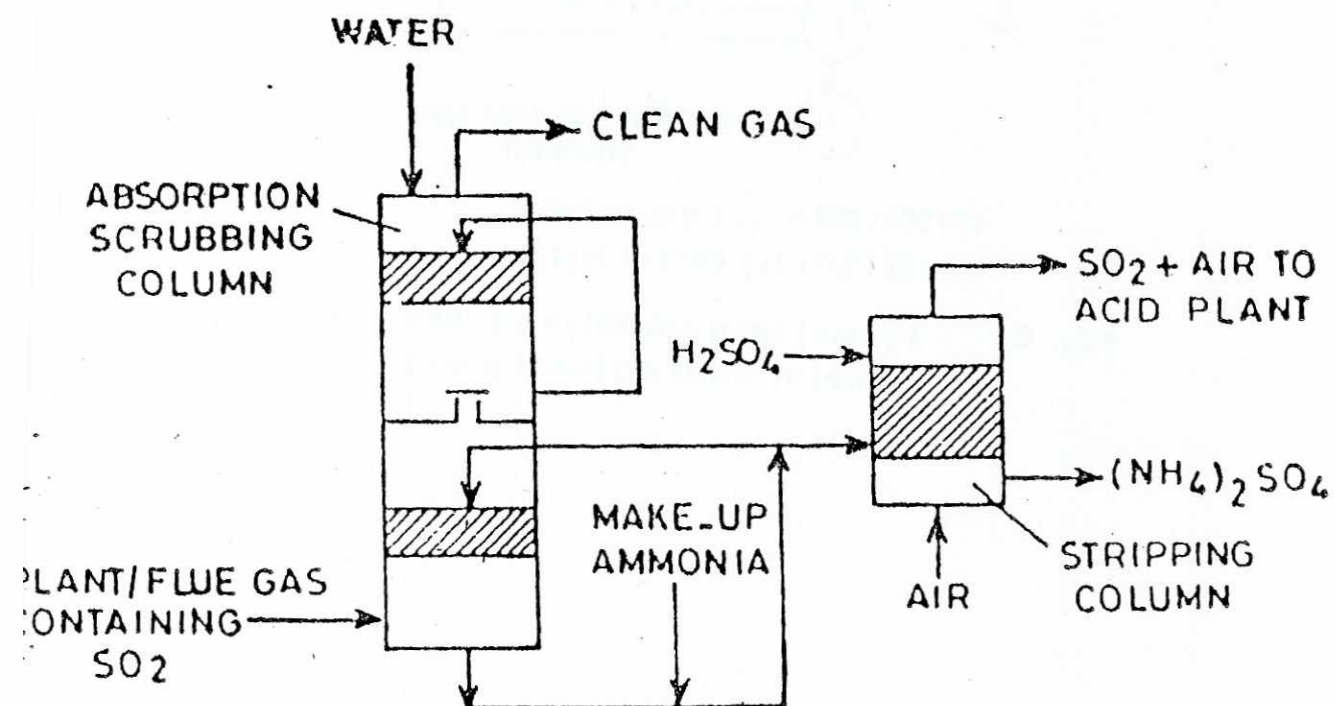


Fig. 8c Absorption of SO_2 in ammonia