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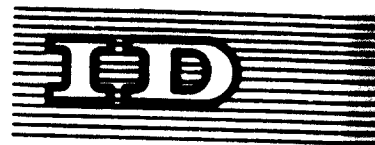
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POLLUTION CONTROL
AND THE IRON AND STEEL INDUSTRY[1]

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SUMMARY

Industrial processes, including iron and steelmaking plant, can pose significant health hazards to employees and to people living nearby, as a consequence of their production of large quantities of particulate matter and noxious gases. Industry is concentrating in urban areas, resulting in an increasing standard of living but a continually declining standard of living environment. It is the latter that must be reversed, for clean air and clean water are costly natural resources, more so than the installation and operation of pollution abatement devices for they cannot be replaced. Further, air and water know no political boundaries and their cleanliness must be conserved for the future.

A computer model was made for a conventional W. European coastal iron and steelmaking plant of nominal size (2×10^6 t of liquid steel/year) with 'middle of the road' pollutant values and practices adopted, to calculate the input and output material tonnages and pollutant data for the individual processes involved. A cost balance is calculated for this normal type of W. European plant and it is shown that the cost of reasonable pollution control to existing standards is quite small.

C O N T E N T S

1. The Scales of Pollution.

We have learnt in the last 50 years that matter can be turned into energy. There is then a single unified system from one end of the cosmos to the other; in the last analysis everything is energy. The sun's energy is apparently limitless. If we cut down our forests or overgraze our grasslands what was productive land can become desert If we overload our waters with sewage, nutrients and algae consume its oxygen, fish die and decompose.

We must be careful we do not overload the self-repairing cycles underlying all living systems. The regenerative powers of life which can survive earthquakes, typhoons, glaciations, etc., are astonishing. However, we must not destroy the balance. In our world we have a certain stability or dynamic reciprocity of living things which depend on one another in an intimate and inescapable way.

We have come to recognise that a country's degree of development to provide its inhabitants with a high standard of living is usually associated with a greater tendency to upset the balance of natural systems, to use up natural resources and to discharge waste products into the environment. We have just not recognised, to our cost, that clean air and clean water are just as much natural resources as are the ore and coal we need to make iron and steel. To finally make 1 tonne of steel we need upwards of 150 tonne of water. Some of this water is itself polluted in absorbing pollutants from the gases formed in iron and steelmaking and coking processes before they are vented to the atmosphere.

The pollution of the environment in developing countries is generally increasing. Much of this is due to the continued annual growth rate of about 4% in the use of fossil fuels which is expected to continue at least to 1980 when electricity generation will have doubled itself in most developed countries. This should be approximately true for Europe but not for the U.K. (probably a 45% increase by 1980), where the increase in the use of natural gas in the last 5 years has inhibited the electricity demand. Japan has an average growth rate for electricity demand of about 12% per annum and should double her electricity generated by 1980. Most of this electricity will come from fossil fuel-steam power stations which are currently emitting vast amounts of SO_2, CO, and hydrocarbons to the air and pose serious problems of thermal pollution of watercourses.

1.1. Environmental Considerations.

We have come to recognise in developed countries that without correct planning control and management, many industrial products would have a detrimental effect on the environment. The developing countries of the world are undergoing in general a transition from an agrarian economy, with relatively land and labour-intensive production, to an industrial economy, with relative capital-intensive production. In this industrializing process, positive net investment usually occurs at a more rapid rate at some places than at others, and fastest in some urban areas especially those at transport terminals. Because production involves the use of factors other than capital, especially labour, urban areas with a greater amount of capital tend to become centres of population growth, and urbanization begins to occur as the percentage of the total population residing in these areas begins to increase.

As industries and people agglomerate in certain areas, their production and consumption activities tend to produce external effects. Some of these are desirable external economies and utilities, better social and educational facilities, roads, transport, higher wages etc. They tend to promote the further economic and population growth of the urban areas. Possibly the most detrimental and undesirable external effect is environmental pollution in its broadest sense. This can be said to occur when the consumption or production of one person or group of persons adversely affects the utility or production of others through the emission of undesirable matter or energy (pollutants) into the physical or social environment. Such emission is dangerous when too much of it occurs or concentrates in one place.

We should not leave a legacy of air pollution and water pollution to the next generation. The tremendous increasing rate of industrial growth over the last twenty years has brought affluence to many so called developed countries but it has also brought this increasing pollution.

1.2. Air Pollutants and Health

There are many varied effects of atmospheric pollution on man, other animals and the environment in general. Some of the more significant ones are mentioned below.

Particulates, sulphur oxide, sulphur dioxide, nitrogen oxide, hydrocarbons (either separately or in combination as smog) cause decreased visibility, unpleasant odours, eye irritation, damage to respiratory systems, damage to materials of many kinds (e.g. building materials, metals, nylon, rubber, fabrics, etc.,), and serious damage to vegitation. Carbon monoxide in sufficient quantity affects the nervous system of humans and can cause serious health defects and death.

Fluorides in sufficient quantities are detrimental to animals and vegetation. Plants store fluorides and can cause adverse effects and death to animals that eat the plants.

The effects of pollution on the health of the populace in the U.S.A. has been estimated conservatively at 2.4×10^9 dollars per year[1].

Calculations of the cost to manufacturers of installing pollution control devices are meaningless if account is not taken of the loss to society caused by the increased deaths resulting from this pollution, even if one just calculates this loss in terms of their earning power projected to retirement age[2]. The net cost to society of such deaths caused by pollution calculated materialistically in this way in terms of gross material income loss is far greater than the cost of pollution control.

The effect on buildings and materials although large is difficult to estimate. In developed countries with increasing concentrations of motor cars in cities, the effect of a contaminated air environment is a matter of a natural concern. There is an increasing citizen demand in developed countries for a cleaner environment. Industries of these countries now have a responsibility for cutting down such emissions and in finding the solution to the environmental problem.

It is no longer necessary in the United States, for example, to prove there is actual damage to health from a pollution source before that source is required to take corrective action. The onus in the future will be on the potential polluters to prove their effluents meet quality standards, or are indeed harmless.

The main sources of their pollutants come from the internal combustion engine, industry, and from coal and oil-fired electrical power stations, generally in this order. Vehicles in the U.S.A.

in 1965 produced 60% of these pollutants, the major one in this case being carbon monoxide (CO). In order to appreciate how efficient a source of CO is the internal combustion engine, we need only consider the fact that each gallon of fuel (weighing approximately 2.7 kg) as it burns yields ~1.35 kg of carbon monoxide. In the same year industry produced 16% and power stations 14% of the air pollutants. Despite the imposition of some control, air pollution is increasing at an alarming rate in developed countries. There are different philosophies regarding pollution control in different countries. In the U.S.A., for example, air quality standards are laid down to 'protect the public health' and industry is obliged to conform. Maximum permitted sulphur contents for fossil fuels that can be used by industry have been stipulated for some years now. We in G.B. accept the policy that we have no sound scientific reasons for adopting particular air quality standards nor do w know of a relationship between emissions and their effects at ground level. We think we shall get acceptable air quality if we control emissions, and we expect industry to play its part.

We can divide the air pollutants into the visible and invisible.

1. Smoke comprises suspended solid particles (less than 1 micron), unburned hydrocarbons, and tarry droplets caused by incomplete combustion.

2. Grit (1-500 microns) and dust (less than 1 micron) are produced mainly by industrial concerns and comprise larger particles than smoke and these tend to be airborne for shorter periods. To offset this, the present policy is to blow out grit under pressure from high stack chimneys so spreading the waste in smaller concentrations but over larger areas. This applies to SO_2 emissions also.

3. Smog is a mixed suspension of solid pollutants from combustion

   in fog or mist. Fog inhibits dilution, and CO and SO_2 are

   particularly dangerous here. Recent work shows carbon monoxide's

   role in the production of nitrogen dioxide aids a synergistic

   effect with SO_2 to form sulphuric acid aerosol.

Invisible

Invisible gases are many but SO_2, of the sulphur compounds
and CO are most harmful. The ambient air standard for SO_2 is 0.03 ppm
in the U.S.A. It has not apparently been proved dangerous to
health at lower levels than this, but damage to plant life and
property is evident at higher levels. SO_2 is very dangerous when
combined with, say smoke, when a synergistic effect is produced. SO_2
has a relatively short residence time in the air for it is readily
absorbed on surfaces.

When SO_2 is absorbed on particle surfaces, it can then react
often with water and when precipitated the rain falls as dilute sulphuric
acid. SO_2 is emitted when solid and liquid fuels - coal, coke,
tars, heavy petroleum products, (which usually contain sulphur) - are
burned. The production of SO_2 is therefore very widespread. It is
also produced in non-ferrous extraction industries in the roasting,
smelting, and converting of sulphides, in sintering and pelletizing
of iron ores, and in the manufacture of sulphuric acid and production of coke
in coke ovens.

Carbon dioxide is not toxic but there is a rise in the ambient
quantity of about .25% yearly due to the increased use of fossil fuels.
The level of CO_2 in the atmosphere may reach such proportions that the
photosynthesis reaction with land plants and sea algae cannot restore
the oxygen content and plants will die and the sea will become polluted.

The effects of the oxides of nitrogen must be evaluated with caution. Nitrogen oxide, as mentioned, accelerates the photosynthesis of SO_2 to SO_3 or sulphuric acid arerosol. We suspect nitrogen oxides have an effect on human health from the results of experiments with animals but we have no definite proof[3-6]. We can remove NO_x emissions but this could be nearly impossible on an industrial scale because of their ready production in high temperature processes[7].

Industrially produced CO (about 12% of the total annual production in developed countries) does not compare in magnitude with the daily urban dose of CO one can get from automobile exhaust, or from cigarette smoke. Carbon monoxide is dangerous, particularly for people with a history of heart or respiratory disease in confined spaces, such as tunnels, garages, coke ovens, or near blast furnaces.

Hydrocarbons are of varying toxicity. In steel plants they are emitted from coke ovens, by-product plant, degreasing vats, etc. The aromatic hydrocarbons in coal-tar gases are high carcinogenic and have been found in appreciable concentrations in steel plants and the surroundings. A high instance of respiratory cancer and of bronchitis has recently been found among coke oven workers[8].

Urban aerosols contain appreciable amounts of carcinogenic aromatics (usually particulates) that have been suspected strongly of being the cause for the greater instances of lung and gastric cancer in populated areas[8-11]. SO_2 and NO_2 are probably mutagens and lead to chronic diseases.

Various fluorine compounds are emitted in aluminium reduction plant, some sinter plants, and in alloy steelmaking where flurospar is being used in appreciable amounts. They produce fluorosis in cattle around steelworks.

Water Pollutants

Like the atmosphere, the earth's water resources are limited, generally as regards location and are unevenly distributed. We recognise water as contaminated when it is not suitable for (a) domestic use, (b) industrial use, (c) other uses, such as agricultural ones including wildlife and fish propagation etc. (a) and (b) represent far greater control problems than (c).

One half or more of the liquid or liquid-borne pollutants discharged into watercourses come from four industrial types of plant, chemical, pulp and paper, iron and steel and petroleum refining[11]. Unless such pollutants are sufficiently diluted serious effects can occur. If the organic materials in the effluents increase the B.O.D. in the watercourse, aquatic life is seriously endangered. Some effluents contain toxic substances that can damage or kill aquatic life. Suspended solids in the effluent can become deposited so thickly on the bottom of watercourses that organisms on the bottom die, causing a reduction in the food supply of fish which may hence also die. Effluents also often discolour the watercourses into which they are discharged and frequently produce undesirable odours or tastes. For example, drinking water should contain <0.001 mg/l of phenol which imparts an unpleasant taste. Also phenol can impart an unpleasant taste to fish that are taken from such water, especially if it is salt water.[12]

Thermal pollution caused by discharging heated water into watercourses can cause some compounds to become more toxic to aquatic life, can alter the reproduction rate of some organisms, can reduce the different species of organisms, can reduce the oxygen dissolved in the water, and can increase the growth of some plants that produce taste, odour or colour problems.

The main pollutants in water used in the steel industry are suspended solid particles, dissolved hydrocarbons, acids and phenols, cyanides, thiocynide and ammonia.

On intergrated works about one third (about 50 tonnes) of the water needed to make a tonne of steel is used for cooling furnaces, one third for cooling condensers on steam-driven turbo blower and generators, and the reaminder is used for the rolling mills, cooling gases, quenching hot materials, removal and carrying of solids to central collecting and disposal points, for steam raising, and hygiene and amenity purposes. The actual water consumption (loss by evaporation mainly) is about 5 tonnes per tonne of steel. As far as the water resources for particular works are concerned this consumption may be made much greater by the dischar, · of slightly polluted water to water courses, (sea, river estuaries, or polluted inland waters).

The conservation of water for recirculation, the disposal of effluents, and the prevention of watercourse pollution go hand in hand and hence their treatment is a common problem.

1.3. Environment First

We are realising the dangers of pollution. We have learnt that large cities, because of their size, rather than their location, are liable to such hazards as sunshine smog (e.g. Tokyo, New York, Paris). Inland from Los Angeles, California there are mountains large enough to prevent the air over the city being dispersed far afield by sea breezes and hence their sunshine smog is a major problem. It is a combination of pollution and a location in which fog naturally occurs that is the cause of the worst smog. Thus, it is only in some places that certain kinds of pollution become a problem and only when experiencing certain kinds of weather that this could happen. It is attractive to think ·

that we can switch on a device to eliminate air pollution only when
the weather is such as to make the pollution harmful. However, the
steel industry works continuously regardless of weather and such a
practice would be more expensive than existing continuous pollution
abatement. In general, the capital cost of such pollution control equipment
is within the range of 4 to 15% of the capital cost of the associated
iron and steel plant and operating costs are about 35% per annum on
the capital cost of arrestment plant. This is not too high a price to
pay when adequate dust and waste recycling is practiced, which can often
defray most of the operating costs (e.g. see Section 6.2.).

Water and air pollution in developed countries are most severe
in areas where the population density is high. It is not surprising
really that the Japanese suddenly passed 14 Laws dealing with pollution
and the environment in 1970. The growing awareness of the public to
the effect of pollution on their environment has been instrumental, to
a greater or less extent, in preventing the building of a new steel
plant in Maasvlakte, near Rotterdam and the Hook of Holland, the
discharge of effluents to the Houston Ship Canal by Armco Steel which
meant the coke ovens and blast furnaces had to shut down, the early
start of production of Kobe Steels, Kakogawa #2 blast furnace, soon
after completion of construction until pollution control questions
had been settled with the civic authorities.

As pollution control standards become more stringent in developed
countries with high population densities the costs of pollution control
for industry will increase due to stricter standards being suddenly
enforced, due to inflation, and due to the geometrical rise of costs
with linear steps in efficiency of contaminant removal at the higher
efficiencies of greater than 90% for particular proved techniques.

Thus pollution control systems will have to be designed with an eye to the future. Adequate space in engineering construction is necessary so that existing pollution control systems can be enlarged, or otherwise modified, to cope with more stringent emission standards. These difficulties facing industry in developed countries could well encourage them to export their pollution by financing iron and steelmaking plant in developing countries where pollution control standards are not so stringent but retaining, themselves, the rolling, finishing, and marketing facitities for the steel product. Alternatively, it may become with ever stricter pollution standards, more economical to think of a different method of making steel that inherently produces less noxious pollutants, rather than to install more complicated pollution abatement systems into existing plant.

Coal and oil will remain our chief pollution problems in power generation and industry to the end of this Century and hence low-sulphur varieties are in great demand. For example, in the U.S.A. it has been estimated that more than 50% of the SO_2 in the atmosphere comes from power stations fired by fossil fuels, about 50% of the nitrogen oxides, and about 25% of all the particulates (industry provides most of the particulates). We have no efficient and economical way of desulphurising the gases or the fuel. Discharging the gases through high chimney stacks up to 450 metres high is the general method used, and is a partial solution only to the problem. To solve this pollution problem a developed country may decide, in order to satisfy the increasing demand for electricity, to generate electricity supply in larger capacity, but fewer power stations fired by, say, coal. This would simplfy the pollution control problem giving an economy of scale impossible among many separate industrial power plants each generating its own electricity. Already in the U.S.A., regulations have been set by EPA requiring a 70% reduction is SO_x emissions from 4

large power plants in Arizona, New Mexico (Four Corners region) and Utah[13]. This could well indicate there a pattern for the future.

2. Pollution Sources and Abatement in Iron and Steelmaking Plant

In the conventional steel plant ~65% of the energy used to finally make a tonne of steel is derived from coal, ~15% comes from natural gas, ~14% from electricity and 6% from oil. The ironmaking plant comprising coke-oven plant, ore-preparation plant, and blast furnaces uses ~60% of the total energy needed to make steel. The blast furnace with oxygen-steelmaking is the most energetically favourable route to steelmaking and will still be widely used for a long time, despite the fact it produces more pollutants/tonne of liquid steel than its nearest modern competitors on an energy basis, it is more capital intensive (large plant ($\geq$2 x 10^6 t/year) being more economical). These competitors, which are probably more of current interest for developing countries with particular local conditions, are the shaft prereduction furance with electric steelmaking process, the rotary kiln with electric steelmaking process, and the fluidised bed prereduction process with electric steelmaking. The second process uses coke and electricity and the others, natural gas and electricity.

Because of its relatively secure future and current widespread use, the conventional plant, whose processes contribute significantly to environmental pollution will be given detailed consideration in this chapter and calculated results from a computer model for an average W. European seaboard plant of nominal size (2 x 10^6 tonnes of liquid steel or 1.885 x 10^6 of crude, or raw, steel per annum) will be given and discussed together with a cost analysis in subsequent chapters. Normal 'middle of the road' figures and practices are assumed to demonstrate the costs of pollution control are relatively small.

2.1. Air Pollution Sources and Abatement Devices

We can classify the process plant into three main cateogries. A) Ironmaking; B) Steelmaking; C) Iron and steel foundries, refractory shops, and rolling mills and furnaces. Also, the efficient abatement techniques for particulate matter fall into three main categories and they are i) the high energy scrubber, ii) the electrostatic precipitator, and iii) the fabric filter system.

A) Ironmaking.

1. Cokemaking. There are two forms of secondary emission from coke-oven batteries:

(a) Continuous emission during cooking from the doors and lids of the ovens.

(b) Intermittent emissions. Of this ~60% occurs during charging, ~30% are evolved during pushing (or discharging), and ~10 vol.% occur during waste water quenching of the incandescent coke.

Control of coke oven emissions to the air is not satisfactorily developed as shown in Table 1a) by the emissions estimated for the coke oven plant in our model producing 2700 day of coke. Even after cleaning, the emissions into the air are quite high (0.63 kg SO_2, 0.12 kg H_2S, 0.7 kg of gas, 2.0 kg dust, all per tonne of dry coke). The model plant uses a quench tower and has none of the modifications designed to reduce emissions discussed later.

We have come to recognise over a number of years that control of atmospheric pollution by these emissions is essential both for new and existing coke oven plant. Several systems for pollution control have passed through the initial development stage, but the practical difficulties are not well known. There is a world of difference between an outline scheme and a successfully working system. We are achieving the know-how and experience gradually, so we must take great care over the engineering

detail in design. Some of the main techniques used for reducing emissions will be briefly discussed.

Continuous secondary emission during coking is a constant problem with slot ovens but new techniques and equipment for sealing ovens are being developed[14]. To avoid undue emissions during charging several systems have been tried, the most recent comprehensive investigations being carried out at the James Loughlin Works, Pittsburgh[15]. These systems are of three types:

(a) those involving variations in conventional charging,

(b) those which use a charger fitted with devices to collect and clean the emissions (usually wet scrubbers of the mechanical or Venturi type

(c) those consisting of pipeline charging of preheated coal into the ovens which have centralised wet scrubbing systems with connections to all charging vents.

In category (a) the most successful, I believe, is the sequential charging system operating now for more than a decade at the Avenue Plant, Chesterfield, England[16] which works best with a double collecting main to give good suction from each end of the oven.

With type (b) all the modifications are the same in principle. They differ only in the method of scrubbing the gases and in the number of scrubbers used. The coal here is charged into the oven through a telescopic spout and the gases evolved are collected in an annular duct around it. They are then ignited and cleaned before discharging to the atmosphere above the charger.

With type (c) the only operating system is at Ironton, U.S.A.[17] but the system is being considered by the British Steel Corporation for some of its new plants. Here preheated coal enters a sealed oven through a sealed system eliminating the pollution problem at the oven but the

preheated gases must be cleaned of fine coal dust. The emissions

during pushing are collected by special hood equipment.

Other techniques for collecting emissions during pushing and

quenching are the rotating bed continuous quencher. The coke is pushed

into a hopper, sealed during the pushing operation to the oven, and

discharged as a shallow bed on to a rotating table when it is quenched

with about one-third the amount of water used in quench towers. The

steam evolved is cleaned in a wet scrubber and vented to the atmosphere.

Another technique is the Halcon-Allen Hooded quench car system which

has not yet been fully tried in practice[16].

Quenching of the hot coke after pushing from the ovens, where

the emissions go into the atmosphere, is usually done by spraying it

with water in a quench tower, as in our model. Tar droplets and dust

are removed from the steam by irrigated baffles. Lower-type baffles

in quench towers, for example have reduced dust emission/quench of an oven char

from 2.7 kg to 0.3 kg. Other pollutants carried with the steam are

emitted to air. This can be excessive if contaminated waste water from

the by-product plant is used for quenching and quite large amounts of

ammonia, phenols, vapourised oil and hydrogen cyanide are emitted to air.

If such raw polluted water is to be used it should be first cleaned of

tar and oils, and then cleaned biochemically to reduce its phenol,

thiocyanate and cyanide contents to < 1 g/l.

Dry quenching, where the dust from the coke is used for steam

raising and power generation, is an example of _increasing_ the energy efficiency

of the process with a _reduction_ in air pollution

Emission of SO_2 from coke oven battery stacks occurs when the

ovens are heated by coke oven gas containing hydrogen sulphide (in the

model we have taken 50 vol.% of the gas make as being used for heating

with no removal of H_2S as being typical). The situation would be vastly

improved if hydrogen sulphide were cleaned from the coke oven gas (for example, by the Stretford process) to be used for heating to $< 3 \ g/m^3$. This is not normally done, unless the gas is sold for domestic use. When blast furnace gas is used for heating the ovens, emissions of CO from the stack could be greatly reduced by the installation of gas tight vents with hydraulic-shutting devices in the oven-heating system. In the by-product plant, to reduce the temperature of the coke oven gas before extracting benzole, water is often used. The water, if it is subsequently cooled in a cooling tower, does emit cyanide compounds and hydrogen sulphide. To reduce this emission the coke oven gas can be washed with an ammonia solution. The plants using ammonia in this way do achieve a high degree of cleaning and usually a marketable by-product.

We must strive towards:

(a) efficient charging of ovens without smoke emission,

(b) the elimination of gas leaks,

(c) the installation of closed coke cooling systems to avoid harmful air emissions in quenching towers.

(d) the elimination of harmful emissions in the by-product plant downstream from the coke ovens,

(e) fuller utilization of residual products,

(f) provision of flares for burning the gas if the gas extractors fail.

2. Ore preparation. There are many pollution problems in ore preparation. Clamp calcinations of ironstone ceased to be legal in 1969 in Great Britain. This was one of the problems that defied satisfactory solution. The product was dusty and the steam, smoke, and fluoride emissions were hazardous to farming.

Quite a large proportion of the total dust emitted in integrated plant comes from the ore unloading, crushing, screening, and bedding operations (secondary dust) including dust whipped up by the wind from

sintering and/or pelletizing plant. We could call this 'outdoor secondary pollution . This can contribute more to local dinginess than primary emissions. All one can do is to provide good housekeeping practice on the plant, use as much covered storage for ores as possible, and use large fans as air exhausters with dust arrestment plant (cyclones, wet washers, baghouses, electrostatic precipitators). The fact that permissible emission standards can't generally be set, should not be a deterrent from good housekeeping. A significant amount of money is being lost here as can be seen from the model results.

There is also secondary indoor pollution which is mainly dust with some SO_2. In the model we have chosen a relatively low-sulphur ore ($<0.05\%$ S) and hence our emissions of SO_2 (primary and secondary) are about 0.001 t/t sinter. Most of the SO_2 from sintering is, of course, primary emission from the stack and cleaning the gas of ten times this SO_2 content is not normally considered. However, at Magnatursk where high-sulphur ores are sintered, the SO_2 in the stack gases is 0.6 -1.0% by volume and the pollution problem would be acute for the town if this gas were emitted to air. They, however, desulphurise the gases with a claimed efficiency of 85% by spraying with a limestone suspension or a magnesium sulphite suspension. A specific investment of 2.0 roubles/100 m^3 of cleaned gas is claimed for the latter process[19].

For cleaning the primary dust emissions from the wind box and the secondary dust emissions from the material handling operation , multicyclones, electrostatic precipitators, fabric filters and scrubbers are in use, to clean the dust content to <0.115 g/m^3 which is the required standard emission in Great Britain now for a new plant. An assessment of current practice in 1969 showed that the average total emission to air was $<0.2\%$ of sinter made[20] (0.19% is used in later calculations using the model and

can be evaluated from Table 2.).

Wet residues from other gas cleaning systems (e.g. blast furnaces) and the scale pits, after adequate dewatering are normally returned to the sinter strand. The percentage fed back in this way does depend on the sinter plant capacity and the quality of the residues. Dry dust from the blast furnace dust catchers is usually preferred to wet dust residues.

3. Blast Furnaces. The secondary dust problem is quite severe in localized areas. At the place where the material is charged into the blast furnace hoppers, the dust concentrations can be as high as 300 mg/m^3 in the surrounding air. This can be reduced by the suction method and later filter bags to 50 mg/m^3 using ~2.5 m^3 of air/s/t of material. Similar equipment can be used at screens for ore, sinter, limestone, and coke. The problem of dust removal in the skip is not solved, but the best solution is the suction method.

The primary dust problem is mainly solved, gas cleaning techniques being well developed, often to give clean gas of < 5 mg of dust/m^3 so any gas emitted to atmosphere does not increase the dust pollution greatly. The problem of gas emission from the bosh has not been solved.

B) Steelmaking

Oxygen converter processes. The use of oxygen in steelworks should be discussed first with the problems it introduces because of the widespread use of pneumatic steelmaking methods and the decline of open-hearth steelmaking in most developed countries (except USSR where 80% of steelmaking is carried out in open-hearth furnaces).

The blowing of pure oxygen generates considerable quantities of pollutants consisting mainly of fine iron oxide given off as brown fumes during blowing (a loss of 1.8 to 2.1% of the iron charged to the L.D. Converter).

Neglecting the energy required to produce the oxygen used, this represented a much quicker way of producing steel and a reduction in the energy required by a factor of about 3. During the 1970's the use of oxygen blowing in the basic open hearth was normal practice but the resulting, very obvious air pollution from their inefficient cleaning systems, becomes often the deciding factor in replacing them by L.D. converters. As an illustration of this latter point we can quote the situation during a temperature inversion which occurred at the Fairfield Works of U.S.S. in February 1971 which had a melting shop of 12 basic open hearth furnaces. A court order put the Works on a 'stand by' basis because of pollution until the weather changed and the local environment improved.

Since as mentioned ~1.8% of the charge (~18 kg/tonne of steel) to the L.D. is blown off as brown fume and most authorities would agree an acceptable maximum level of dust emission in the gas vented to atmosphere would be 115 mg/m^3 (~35 g/tonne of steel produced), it is clear a very large quantity of dust is captured when the cleaners are working satisfactorily. The gases evolved at 1400 to 2000°C are collected in hood above the converter and then treated by one of two main methods; burning of the gases (complete or partial combustion systems), or treating them without combustion (supressed combustion system).

The complete combustion system is tending to be ruled out today on the grounds of lower flexibility, reliability and economy of operation than the others for which the service conditions are less ardous since the gases are not burnt. Partial combustion systems are also considered weak on flexibility and economy as compared with the suppressed combustion systems, which are relatively smaller and lighter in weight[21].

When considering air pollution on L.D. and Kaldo, which are top-blown oxygen converters, and thos n Q-BOP, OBM, and LWS which are

bottom -blown converters, where similar gas cleaning systems of, say the suppressed combustion type and hoods for the off-take of the converter gases are used, a satisfactory hood system is of prime consideration to avoid undue leakage of gas and fume. Then, any reasonable gas cleaning system can reduce the dust content to <100 mg/m^3 for atmospheric emission which currently is below the maximum legal limit of 150 mg/m^3 for several countries. However, the latter requires one dust cleaning unit of venturi scrubbers/converter but the potential heat of the gas recovered is between 8.4 and 10.4 MJ/t of liquid steel produced. In the model we have considered the gas to be cleaned by electrostatic precipitators, the dust being collected in a dry condition. What I would stress here, is that if it is desired to increase the steel output from existing plants then the most serious effects are felt at the gas cleaning plant. For example, if a complete conbustion system were chosen then one should make sure the air factor selected for the waste-heat boiler is high enough to ensure total combustion of the extra gas volume caused by the higher output is completed even during peak carbon-removal rates, or excessive pollution of the atmosphere will result.

Electrostatic precipitators which are quite frequently used have also limited steel production in L.D. converters considerably in the past due mainly to an inadequate number being provided and the means of rapidly isolating a faulty precipitator so that steel production could continue unabated whilst the faulty precipitator was being repaired and gas cleaning was continuing in other precipitators. The cleaning circuit is only used when blowing, say, a 150 tonne charge in a L.D. converter for about one-third to one-half of the tap to tap time. Yet, if emission standards are in force then it is the cleaning plant that can limit steel production if there is an electrical fault in one of the precipitators, or say a

small explosion. In large thermal power stations it is quite usual for only 2 or 3 days production to be lost per year due to unplanned failures of the cleaning plant. With L.D. plant we should strive towards this efficiency so that gas cleaning is not made more expensive by lost production time. If electric precipitators are used it is a matter of installing enough precipitators for the plant with good isolating valves and crossover ducting so that a precipitator can be rapidly isolated if it fails, and efficient gas cleaning can continue in the others. This may mean a bigger initial capital investment but it is lost steel production time that is at stake, and this extra investment, just as extra intitial investment in buying the best available and most reliable equipment available, is paid off quickly.

Electric Arc Furnaces

The electric air furnace produces dust and fumes during operation. Prior to oxygen lancing, there were no standards imposed on electric arc or open hearth emissions to air. However, when oxygen lancing was introduced to these processes dust cleaning equipment was seen to be essential.

The dust emissions of the electric arc process today with lancing is ~4.6 to 7.0 kg of dust/tonne of steel produced. These are emitted through openings around electrodes, spouts, doors, etc. When the roof is opened, or the doors opened for charging flux additions etc., additional emissions take place. The use of oxygen lancing leads to the greatest rate of emission and concentration of the pollutants, the second highest rate of emission occurring in the melt down period. About 75% of all emissions in the process occur in these two stages. Generally 95% of the dust is 0.5μm in size with a specific gravity of ~4.

The concentration of dust in the gases to be cleaned depends on the particular method of collecting the gases from the furnace and the method of gas cooling. The usual collecting systems are given below.

a) <u>Canopy Hoods</u>

These are evacuation devices separated from the furnace. They are large openings usually located just below the roof of the building but above the crane tracks and act as a general exhaust system for area or building ventilation.

b) <u>Direct Shell Evacuation</u>

A reduced pressure within the furnace shell is maintained by fan suction through an opening at the top of the furnace to give satisfactory dust and fume collection. This method has advantages, over the others, in that the pollutants are collected in a minimum amount of air, and the furnace roof is not covered by a hood. It is the preferred method and is, in fact, obligatory in the U.K. for large electric furnaces. The reduced pressure does not present any noticeable metallurgical problems at least in carbon steel production. The main disadvantage is that it gives a potential CO explosion problem if you do not dilute the gas with ~7 parts of air.

c) <u>Roof Hoods</u>

This device fits on the furnace roof and has openings over or near the normal furnace openings or other sources of particulates, so that when air is sucked into the hood the dust emissions can be collected.

To produce an effluent from the cleaning of arc furnace discharges free from visible solids, i.e., brown fume, requires that the dust content of the cleaned gases be <65 mg/m^3, this requires $>95\%$ dust removal. The possible cleaning techniques are Venture scrubbers, cloth bag pressure filtration, wet electrostatic precipitators.

The Open Hearth - possibly a new lease on life

The open hearth furnace which was the chief user of scrap has been rapidly disappearing (except in USSR) and the electric arc process of producing ordinary steel has increased in importance and become now the main user of scrap. Sydney Steel, Canada are experimenting with the bottom-blowing of oxygen, shielded with fuel oil, through Maxhuette tuyeres (SIP process) in their open hearth shop. If this proves successful and their output is doubled with three of the five open hearths modified in this way then several companies with open hearth furnaces could well be tempted to do likewise. For an existing open hearth shop, with facilities for roof lancing with oxygen, convertion to SIP practice if an adequate fume removal system (e.g., 3-stage dry electrostatic precipitation) with plenty of scrap available would be cheaper than say, convertion to a Q-BOP shop which itself would be cheaper than re-structuring for L.D. practice.

C) Foundary Cupolas, Refractory Shops, Rolling Mills and Furnaces

In foundaries the cupola top gases should be burnt and cleaned of dust to <100 mg/m^3. With open and closed cupolas the procedure differs slightly. In the former the top gases are ignited with a gas/air burner located above the charging aperture and leave the furnace at ~850° passing then to a wet dust collector, a series of spray pipes removes more dust from the gases which are now ~60° which leave via the stack at <100 mg/m^3. In the latter, the top gases enter a dust-catcher before being ignited in a combustion chamber. From here, their heat is extracted in a recuperator used for preheating the incoming cupola air blast and the gases are cooled and de-dusted by spray pipes and then pass to the stack.

The main sources of dust pollution in the refractory shops are the rotary kilns and furnaces used for calciniting and roasting, and the drier

drums. Firing these with fossil fuels results in SO_2 emission and
dust. The gases from the drums, kilns, and furnaces are cleaned usually
in two stages, dry cyclones followed by bag filters, electrostatic,
or wet dust collectors. They leave the furnaces at a high temperature
($\sim 650^\circ$) and pass into a waste-heat boiler before entering the cleaning circuit.
High electrostatic cleaner efficiencies of 98% are necessary to reduce
the dust in the gas to <100 mg/m^3 for emission to atmosphere:
Particles with a high specific resistivity such as magnesia, give low
electrostatic cleaning efficiencies of $\sim 85\%$ and exit dust contents of
~ 500 mg/m^3 even with very slow gas velocities of ~ 0.6 m/s.

2.2. Water Pollution

The mill effluent containing oil (~ 30 ppm) and mill scale
(1 to 5 kg/m^3), as main pollutants, represents 70% of the total quantity
of polluted water in an integrated steel plant. Primary cleaning is
carried out by passing the water through large scale pots which remove
$\sim 75\%$ of the suspended solids to which some oil adheres and some of the
remainder can be skimmed off from the water. Then, if the oil content
of the water is <15 ppm, finer solids can be removed by sand filters.
The latter process is becoming more popular as it obviates the use of
chemical reagents which always involve disproportionately high operating
costs. This apart, the aim in steelworks should be towards a closed,
neutralised water system. Thus a continuous system like this with recycling
is the best for avoiding the pollution of watercourses, since no
polluted water is discharged. However, very efficient cleaning systems
are needed in this case.

Emphasis must be given to the treatment of waste water containing
emulsified oil. This waste water should be kept separate from the main
stream because it represents a particularly difficult treatment problem
and the results are usually unsatisfactory. The highest possible degree

of recirculation and reuse is necessary because of this difficulty in treatment. Chemical treatment, such as the addition of iron salts and lime followed by flotation is often used. Various chemicals, including acids (often the acid in waste pickling liquors from the same plant is used), and magnetic separators have been tried to break up the emulsion prior to oil separation in skimmers and plate separators.

More emphasis must also be given in the future to the purification of acid effluents containing iron. In acid pickling plant with sulphuric acid, ferrous sulphate is separated as a hydrate the acid being regenerated by vaporisation at ordinary pressure (Zahn process) or under vacuum (Lurgi or Ruthner processes). More ferrous sulphate is normally produced than can be sold. When steel is pickled in hydrochloric acid, the iron salts are recovered from the concentrated spent liquor by spray roasting to give ferric oxide and hydrogen chloride. The latter is absorbed in water or other acidic rinse water for recycling. The volume of pickling solutions and rinse water needs to be reduced for economy, and preferably newer methods of pickling without using acids should be considered[22]. There is also a need to find better emulsion regeneration techniques (e.g. solvent extraction, ultra high rate filtration) to obviate the use of acids or to reduce the amount required for cold-rolling processes so that these emulsions can be recycled.

In coke plants the main sources of water pollution are the ammonia still wastes, light-oil decanter wastes (~40 galls/tonne of coal) containing phenols, cyanides, thiocyanates and chlorides. I have mentioned air pollution caused by waste water coke quenching earlier. Treatment of waste water from the coke plant can be done using the bacteria in minicipal sewerage, using chemical oxidation, or carbon absorption. Coupled with recycling of water, which reduces effluent volumes to a minimum, these practices can avoid potential water pollution.

On the ironmaking plant, pollution of water occurs mainly from gas cleaning with wet washers. It is always more economical to remove the dust dry from the gas to a level of <4 g/m^3 before the gas enters the scrubbers because of the expense of removing sludge from the settling tanks. The water from the wet washers contains cyanides, phenols, ammonia, and suspended dust. Recently vacuum filters have been added to settling tank circuits to extract a sludge with about 20% water which can be added to the sinter charge, the effluent water should contain <100 mg of sludge per litre. Where electrostatic precipitators are used clarifiers and coagulants are often used to further purify the water used for electrode washing. Cyanides should not be oxidised and the water aerated to release hydrogen cyanide to the atmosphere, but should be converted to non toxic cyanates or ferrocyanides by chlorination or adding ferrous sulphate. Newer methods of removing solids from the waste water from ore concentration and sinter plant using coagulants and chlorination are becoming used more so that the water can be recirculated or partially discharged to watercourses. Open hydrocyclones for separating suspended solids are becoming more popular, and so is evaporation cooling of furnaces which reduces considerably the volume of water used. Better methods for H_2S removal from the water are needed.

* In steelmaking processes using oxygen, the waste water contains suspended solids (65 to 70% iron) and elements from the slag making the water acid. The solids are separated usually in radial settling tanks. Hydrocyclones are also used to clarify the water, lime is added to neutralise it, and magnetic fields and flocculants are sometimes used to aid the settling of fine particles to give <150 mg/l of waste water. The steel industry has practised conservation and re-use of millscale, blast furnace dust, sinter dust and fumes etc., for many years. The attraction is obvious saving, as the earlier calculations in the next

section indicate, because of the quantities involved. Also, coke oven
gas, blast furnace gas, slag, soluable oils, some coke oven chemicals and
scrap are conserved for later use. Other solid wastes such as neutralised
pickle liquor sludges and often L.D. dust accumulate about the plant
due to simple technological processes not being available.

The problem or air and water pollution is wide and complex,
but the iron and steel industry must approach it in a positive manner.
In general one can say that future prospects of clean air and clean water
from the iron and steel industry are improving and often fuels of lower sulphur
content are being used. This is mainly because older equipment is gradually
being replaced with modern equipment where pollution control devices form an
integral part of the design of the plant. However, because of the growth
of steel production more attention in the future will have to be given
to pollution control. More scientific research needs to be carried out, and
more international co-operation is necessary to standardise methods of
pollution measurement wnich concern both the developed and developing
countries.

3. A Notional Integrated Iron and Steelworks

(a standard complex producing 2×10^6 t of liquid steel per year on a Western European seaboard site - 90% plant utilization, 330 day year generally assumed)

In this section a plant flow sheet (Figure 2) for the model containing the annual raw material stockyard inputs of coal, iron ore (59%Fe), scrap, and limestone in millions of tonnes per annum is presented. Their main input divisions, the principal process box outputs (e.g. hot metal, liquid steel, etc), and the casting and mill scrap returns are given. For clarity, circulating process returns, apart from scrap, wind and spillage losses and slag quantities are not included on Figure 2.

Table 2 shows "middle-of-the-road" process losses of particulates based on good average plant experience as percentages of either raw materials inputs/process box outputs from Figure 2. The column headed % Recoverable in Figure 2 gives estimates of the percentages that are recoverable in good practice for recycling except for the figure of 99%* for L.D. dust which is an estimate of the percentage we can recover. For example, we do recover more than 90% of the blast furnace gas dust, but not all of it is usable as sinter feed. Wind and spillage losses are calculable in tonnes per annum from the figures in Table 2 and Figure 2. The blast furnace slag make is 350kg/t of iron, and coke oven emissions are given in Tables 1 (a) and (b). Table 3 gives typical water circulating figures for the model.

3.1. General Comments. It may be argued that any process losses dumped around the plant constitute a potential pollutant source whether they be waste products such as slag, L.D. dust, tailings, byproducts such as naphtha or tar, or circulating metal scrap (cropends, machining swarf, offcuts, etc) or dangerous and noxious effluents emitted locally such as cyanides, phenols, H_2S, or SO_2. Strictly this is true, but it is equally the case that to the general public it is the effluent that spreads into their living environment (i.e. their air and their water) outside the plant which constitutes the principal threat.

Plant housekeeping varies from site to site. The percentages that are recoverable in good standard practice are given in Table 2., but more can be recovered depending on the attitude of the operators, and on the sinter feed and sinter plant capacity for example. It has not been indicated in the model, which has 100% sinter

practice and hence ample capacity for all return fines (excluding
L.D. dust to any real extent) just what percentage of the dust, mill
scale etc., should go back into the sinter mix.   This depends on
the policy of the operators and in Table 2 the readily-recoverable
percentages have been chosen.   The rest is wastage and decisions
as to when and how to attempt reduction of this is a matter for
the plant management who know their own economic situation best.

Section 4 - Process Plant Capital Cost Estimates (including pollution control devices as detailed in Section 6)

Basis of estimate - A Western Europe seaboard site, all services and infrastructure requirements provided to plant boundaries.

	Capital Cost US $ million (1973 prices W. Europe)
4.1 Lime Kiln	
One gas fired 200,000 tpa capacity kiln plus limestone handling, feed equipment, lime recovery and distribution	6.5
4.2 Coke Ovens	
Two batteries each of 45 ovens - 90 ovens each yielding 30 tpd coke plus coal handling and charging equipment, pushing, quenching and coke handling and distribution	43.3
4.3 Sinter Plant	
Two strands each capable of 1.15 mtpa max. plus sinter feed hoppers, mixing and feed equipment and sinter breaker, screens and distribution equipment	15.5
4.4 Blast Furnaces	
Two furnaces each 700,000 tpa max. plus two gas cleaning plants plus feed mixing and handling, slag handling and other ancillaries	42.3
4.5 L.D. Furnaces	
Three converters each 75 tonnes capacity plus two gas cleaning units, steel handling and ancillary equipment	32.3
4.6 Electric Arc Furnaces	
Three E.A. furnaces each 75 tonne capacity plus three gas cleaning units, steel and scrap handling and ancillary equipment	14.6
4.7 Continuous Casting Plant	
Two single strand slab casting units each of 750,000 tpa capacity plus ancillaries	45.8
4.8 Ingot Casting Plant	
A 500,000 tpa capacity Ingot casting and stripping unit, max. ingot size 10 tonnes, plus handling and ancillary equipment.	8.5

4.9 Hot Strip Mill

One 56" mill of 1.5 mtpa capacity plus
control and ancillary equipment   106.9

4.10 Cold Rolling & Pickling Line

A one million tpa pickling line, cold rolling plant
and annealing unit, with ancillaries and control   115.6
equipment

4.11 Bloom/Billet Mill

A primary mill and billet mill each of
0.5 million tpa capacity plus ancillaries   31.7

4.12 Rod and Bar Mill

One unit of 0.4 million tpa capacity plus
ancillaries   29.5
                                                    ─────
                    Sub Total   492.8

Plus General Works Services Allocation (25%)   123.2
                                                    ─────
          TOTAL CAPITAL COST ESTIMATE US $ 616 million

Section 5 - Process Plant Operating Cost Estimates

(Annual costs of the process centres shown below include all raw materials, labour, power and fuel (based on 1973 unit prices) but exclude inter-process material transfer values. All estimates are for a W. European seaboard site and assume water, power, fuel and labour availability at plant boundaries. No depreciation or capital charges are included.)

Process	Annual Output			Operating Cost Estimate million US $ p. annum
Lime kiln	0.176	m.t.	95% CaO	1.31
Coke ovens	0.916	"	metallurgical coke	37.80
Sinter plant	2.06	"	sinter feed	27.85
Blast furnace	1.29	"	pig iron	5.14
L.D. plant	1.50	"	liquid steel	15.34
E.A. plant	0.50	"	liquid steel	17.12
Continuous casting	1.41	"	slabs	5.88
Ingot casting	0.475	"	ingots	1.29
Hot strip mill	1.33	"	H.R. strip	8.73
Cold rolling mill	0.91	"	C.R. strip	9.22
Bloom/billet mill	0.425	"	billets	1.36
Rod and bar mill	0.40	"	rods and bars	3.48
			Sub Total	134.52
Plus G.W.S. Allocation (25%)*				33.63

TOTAL OPERATING COST ESTIMATE US$ 168.15 million

Represents $102 per tonne final product (excluding depreciation and capital charges)

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*

The General Works Services allocation (GWS) figure of 25% is typical and includes charges for materials handling, internal transport, Central Maintenance Workshops, Stores, Drawing Offices, Laboratories, General Offices, Canteens, other clerical and medical charges, mechanical and electrical services including connections, etc.

6. Pollution Control Devices - Capital and Operational Cost Estimates

6.1. The classification of Devices and the Approach to Cost Calculations

In compiling the capital and operating cost estimates which follow, a broad definition of control devices is taken to include both classifications given below.

a) Devices that give definite plant economies as well as pollution control for the environment.

b) 'Purer' pollution control devices where the emissions they trap, or collect, do not give measurable plant economies at the moment.

a) Examples of the former type are the devices that clean coke oven and blast furnace gas. Both gases if emitted directly to air as formed pollutants to the general public just like the particulates they contain. However, we recover the cleaned gases for their value as fuels giving a marked plant economy. The particulates we recover are also plant economies but of less importance. Thus cleaning of these gases for use as fuels on the plant has been carried out efficiently for about 25 years. Also, sinter plant dust collection is important for material economies and is not just collected for improvement of the environment now, and for the future, although there are now particulate emission standards for new sinter plant in many developed countries. Mill scale (~70%Fe) in an easily recoverable particulate from the rolling mill effluents. Such recovery is a plant economy and has been carried out on many plants for a considerable time. Using the data in Figure 2 and Table 2 for our notional plant as computer input we can calculate:-

(1) If 75% of the mill scale is recoverable for sinter feed this is approximately equivalent to a saving of 8000 tonnes of finished steel/year.

(2) If the feed materials dust (secondary emission) and blast furnace gas dust (primary emission)(of ~50%Fe, 11%C) are recycled for sinter feed this is equivalent to an iron recovery of ~21000 t/year from the blast furnace.

(3)   If the secondary and primary sinter dust and spillage are collected and recycled this is equivalent to an iron recovery of ~44000 t/year.

Thus, it is possible with the good housekeeping practice assumed in our model for secondary ore and sinter dust and millscale, and good abatement practice for primary dust to achieve on this model plant an extra output of ~76000 tonne of iron/year from the blast furnace due to recycling of materials, reducing the operating costs in 6.2.

b)   Notable examples of the latter type are those for the collection of the primary dust from the oxygen steelmaking plant and from oxygen-lanced electric arc furnaces which gives disposal problems. In our model we have an L.D. plant producing 1.5×10^6 t of liquid steel per annum, from which the primary dust is very fine (~30000 t/year of dry dust containing ~60%Fe with 95% of it $<$5 microns in size).

Small amounts of this dust have been recycled (often/crushed with L.D. slag) to the sinter plant and to the converters but very little of it can be used up in this way. Possible solutions are pelletising the dust for blast furnace use if a suitable mix and process can be developed, or for subsequent reduction to sponge iron in a modified Krupp kiln if the Zn content is too high for blast furnace use [23].

6.2.   Pollution Control Capital and Operating Cost Estimates

	Capital Cost US $ million	Annual Operating Cost US $ thousand
Lime Kiln		
Extraction system on all dust areas exhausting to bag filters including handling, charging and discharge. Kiln gas exhaust scrubbers plus pumps etc.	0.40	35

	Capital Cost US $ million	Annual Operating Cost US $ thousand	(Co

Coke Ovens

Extraction system covering dust emission areas including coal handling and charging plus coke pushing, delivering to multicyclones and wet scrubbers. Irrigated baffle tower for quench fume control. Ammonia stripping and biological treatment for wet emission control on by-product processes and coke oven gas cleaning system.

	1.5	195

Sinter Plant

Cyclone dust control on exhaust extractors from all material handling, mixing, feeder and discharge areas Cyclones plus low energy wet scrubbers for sinter windbox fume extraction.

	2.0	700

Blast Furnace

Cyclone dust control on extractor system from all material handling and charging areas Venturi scrubbers settling pond and thickener plus wet electrostatic precipator on B.F. gas cleaning system. Chemical dosage of bleedoff water prior to final discharge.

	4.7	450

L.D. Furnace

Wet electrostatic precipator treating cooled burnt gases plus thickener, filtering equipment and pug mill.

	6.0	260

E.A. Furnace

As above for L.D. control

	1.0	100

	Capital Cost US $ million	Annual Operating Cost US $ thousand (Cont.)

Casting, Pickling & Rolling

Settling ponds, clarifiers and filters for
collection and recovery of mill scale
from all direct water cooling circuits.
Oil and emulsion collection via skimming
with acid splitting for oil recovery.
Oil mist extraction and elimination from
air exhaust of cold rolling plant.
Acid fume water spray eliminator from
exhaust air of pickling line.
Disposal of iron salts from acid
regeneration.

	Capital Cost	Annual Operating Cost
	6.8	500
Sub Totals	22.40	2,240
Plus G.W.S. Allocation (25%)	5.60	560
TOTAL ESTIMATE POLLUTION CONTROL US $28.0 million		$2.80 million

Capital Cost ($27.8) is 4.5% of Total Plant Capital Cost Estimate.

Operating Cost (excluding capital depreciation and charges) $2.53 million is
1.7% of Total Plant Operating Cost

and

Represents $1.54 per tonne of finished product

6.3 Pollution Control Costs per tonne of finished steel

Output of finished steel (Table 2)	$= (0.330+0.910+0.400) \times 10^6 \text{ t/yr}$ $= 1.64 \times 10^6 \text{ t/yr}$
Total Capital Cost Estimate ∴ Capital cost/tonne finished steel	$= \$616 \times 10^6$ $= \$375$
Capital Recovery Factor (20%)	$= \$75$/tonne finished steel
Actual Cost of Steel $= \$(102 + 75)$	$= \$177$/tonne finished steel
Plant Operating Costs	$= \$1.54$/tonne finished steel
Capital Charge is 4.5% of $75	$= \$3.38$/tonne finished steel
Pollution Control Costs	$= \$4.92$/tonne finished steel

7. <u>Future Trends and Concluding Remarks</u>

In earlier sections the social costs of this increasing pollution
of our living environment were stressed. This policy of increased use
of fossil fuels by ~4%/annum (a doubling time of 17 years) and the increased
demand for industrial metals by ~6%/annum, are main contributors with
the global rise of ~2%/annum in population (a doubling time of 35 years)
and the rise in city and urban population by the alarming figure of 4%/annum.
We, therefore, expect to have to double our capacity of food production,
housing, transport, water and sewage systems, and all the rest of the
goods and services we use. Also, the rising expectations for technological
progress of the developing countries will make a more than doubling of
resources important.

Of all the energy produced about 98% comes from oil, coal, and
natural gas, while water power contributes ~2% and on a global scale nuclear
energy is still negligible. Our energy usage commits us to an increasing
pollution of our living environment and our tendency to live and work in
urban area, where industry concentrates and material standards of living
are higher and opportunities for learning and social organisation greater,
concentrates that pollution locally and increases the dangerous effects
that pollution can have on our mental and physical health and lifespan.
We must reverse this trend of increasing pollution, or at least control
it to a reasonable level, without halting economic progress.

The water pollution disasters in developed countries where the fish
population in inland (e.g. Lake Erie) and coastal waters (e.g. Japan) has
been shrinking dramatically in the last decade and the sudden excess deaths
due to air pollution that have occurred should be a warning to the people
of developing countries of the <u>real costs</u>. The answer may be that
governments should raise ecological matters to the same level as their

foreign office affairs, and actively co-operate with each other over the fixing of standards on emission and policies. We need probably a separate politics on the subject. Some politics are more arbitrary than this would be, for it would have a foundation in scientific fact that would evolve with time so predictions, and corrections, could be made for particular areas and industries.

From Section 2 the major emission and collection problems of existing coke oven and oxygen-steelmaking plant are stressed, new techniques and remedies are discussed. Probably a complete new design of coke oven is necessary for satisfactory emission control. In sections 3-6 it has been shown that for an integrated steelworks of standard European design the cost of pollution control, to existing standards in most developed countries, is _very_ moderate indeed. The total capital cost of good pollution control equipment is shown to be ~4.5% of the total plant capital cost, and the operating costs (~$1.54/tonne finished steel) are only ~1.7% of the total plant operating costs. Further, the cost of pollution control is calculated to be < $5/tonne of finished steel.

If we take a forward, rather than backward view, of this cost analysis believing a position in a developed country's environment has advantages for assessment, then the provision of capital for abatement devices of type b) which include principally the collection of the fume from the steelmaking processes (L.D. and electric arc) accounts for ~1.5% of the total capital expenditure for this integrated plant and the operating costs of this true pollution control plant, less than 1% of the final product costs (i.e. less than $2/tonne finished steel). This seems a marginal cost for appreciable environmental benefit in a developed country, and probably more a worthwhile investment for the future in an undeveloped country. In this instance the L.D. fume and dust has been recovered from

a relatively large volume of gas containing only sensible heat, and neither have been further utilized.

This gas recovery and cleaning problem in these two processes using oxygen is not yet solved. It is receiving more attention because of the increasing investment in these processes, the enforcement of pollution control, and to improve productivity. Both L.D. and electric steelmaking are increasing. The former now accounts for $>50\%$ of world production, and the latter is replacing the open hearth as principal scrap user and could well become the second main steel-producing process with an output exceeding 150×10^6 tonnes by 1980[24]. Electrical energy is rather expensive in most developed countries relative to coking coal, gas and oil at the moment but electric steelmaking from scrap and prereduced material can become attractive if gas or oil become cheaper than coking coal. Also, such steelmaking is more viable as small units and much less capital intensive than the conventional blast furnace - L.D. plant, and has become a significant producer in the developing countries of Latin America.
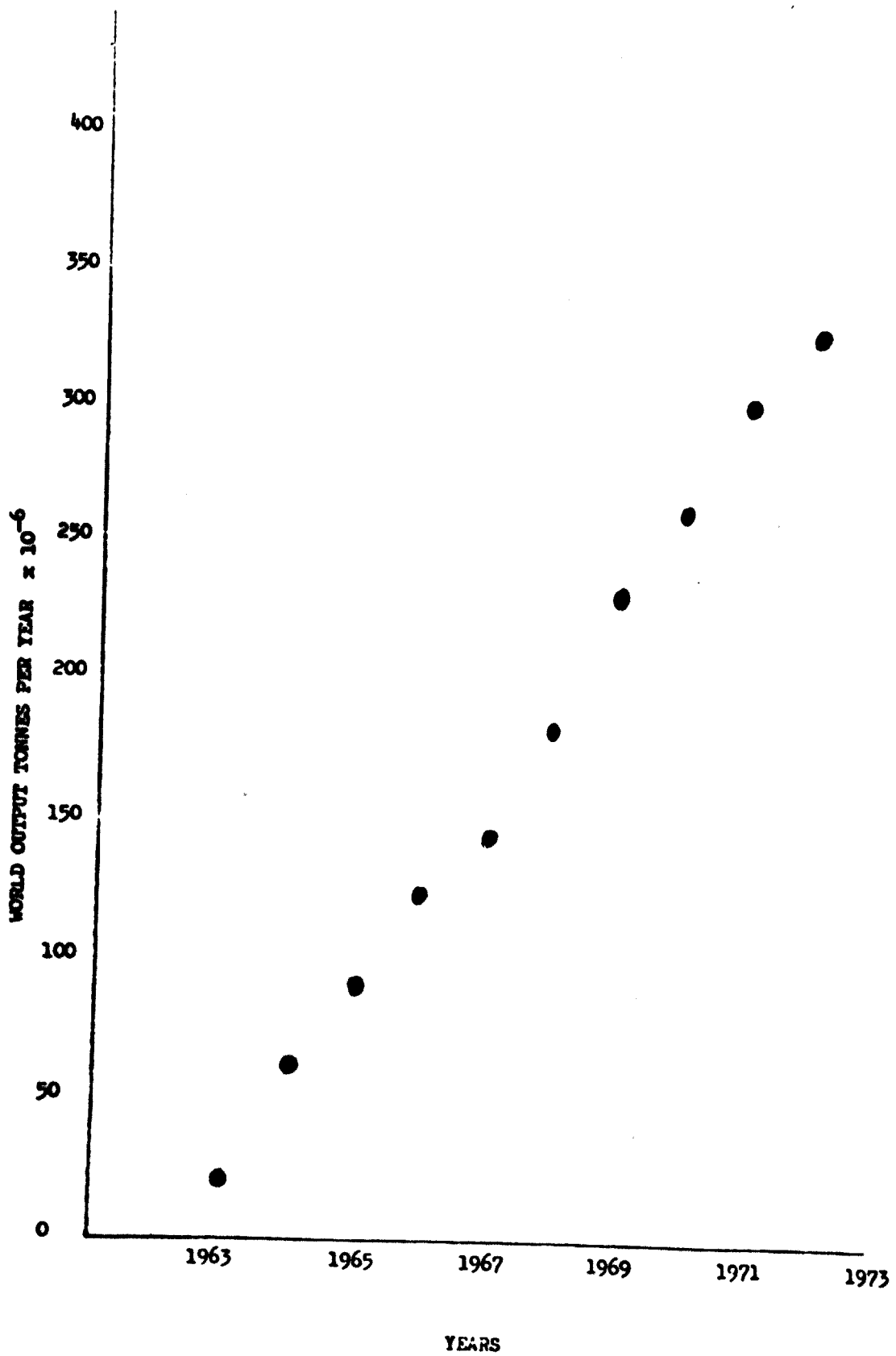
This problem is better tackled by collecting the dust in the minimum gas volume, as was found for large electric arc furnaces, and this solution seems to be the most satisfactory and likely to give L.D. plant economies. The supressed combustion system of gas recovery is clearly becoming that preferred for new plant due to its greater flexibility, reliability and economy of operation. Adopting this system sets the pattern for increased productivity, with the advantages of the gas being recoverable as a fuel (a plant economy already in Japan) and the dust being recoverable in a wet condition for ultimately easier handling for sintering, pelletising, etc., new techniques for the use of this dust to a greater extent for iron recovery should not be far away[23]. Some attempts should also be made to reduce

emissions and turbulance during the blowing period. The use of fluxed sinter or pellets instead of iron ore additions and tuyeres of sepcial design to reduce dust emissions should help.

With regard to the model plant, for which pollution control costs are very moderate indeed more could be done on the pollution side for the control of emissions, which is not really satisfactory for an assumed large number of people living close to the Works. There are quite significant secondary emissions (wind losses and coke-oven emissions) that tend to make the plant and neighbourhood dingy. Secondary emission control, mainly for the benefit of operator visibility and plant cleanliness during changing and tapping of L.D. converters, etc., is receiving serious attention[25]. The relative costs of installation of additional abatement devices or replacements on existing plant is a very difficult question to answer. The same devices built into the design of a new plant can cost ~50% less to instal taking into account any modifications to be made and any additional risks the designers take, and lost plant production time and inconvenience. As a general rule, to aviod lost production time due to breakdowns in pollution control equipment, it is sound policy to buy the best and most reliable equipment available. A minimum figure from our model plant, assuming a reduction in steelplant availability of 2% throughout the year resulting in a 2% loss of sales would increase the cost of the finished steel by another $2.5/tonne.

Figure 1

WORLD L.D. AND L.D.A.C. STEEL PRODUCTION

YEARS

COAL
1.310

IRON ORE
2.230

SCRAP
0.513

LIMESTONE
0.447

0.066

COKE OVENS
0.916

0.211

0.005

0.086

SINTER PLANT
2.060

0.700

0.043

BLAST FURNACE
1.290

LIME KILN
0.176

0.150
0.330

L.D. FURNACE
1.500

E.A. FURNACE
0.500

CONTINUOUS CASTING
1.410

INGOT CASTING
0.475

0.342
RETURNED SCRAP

HOT STRIP MILL
1.330

BLOOM/BILLET MILL
0.425

COLD ROLLING MILL
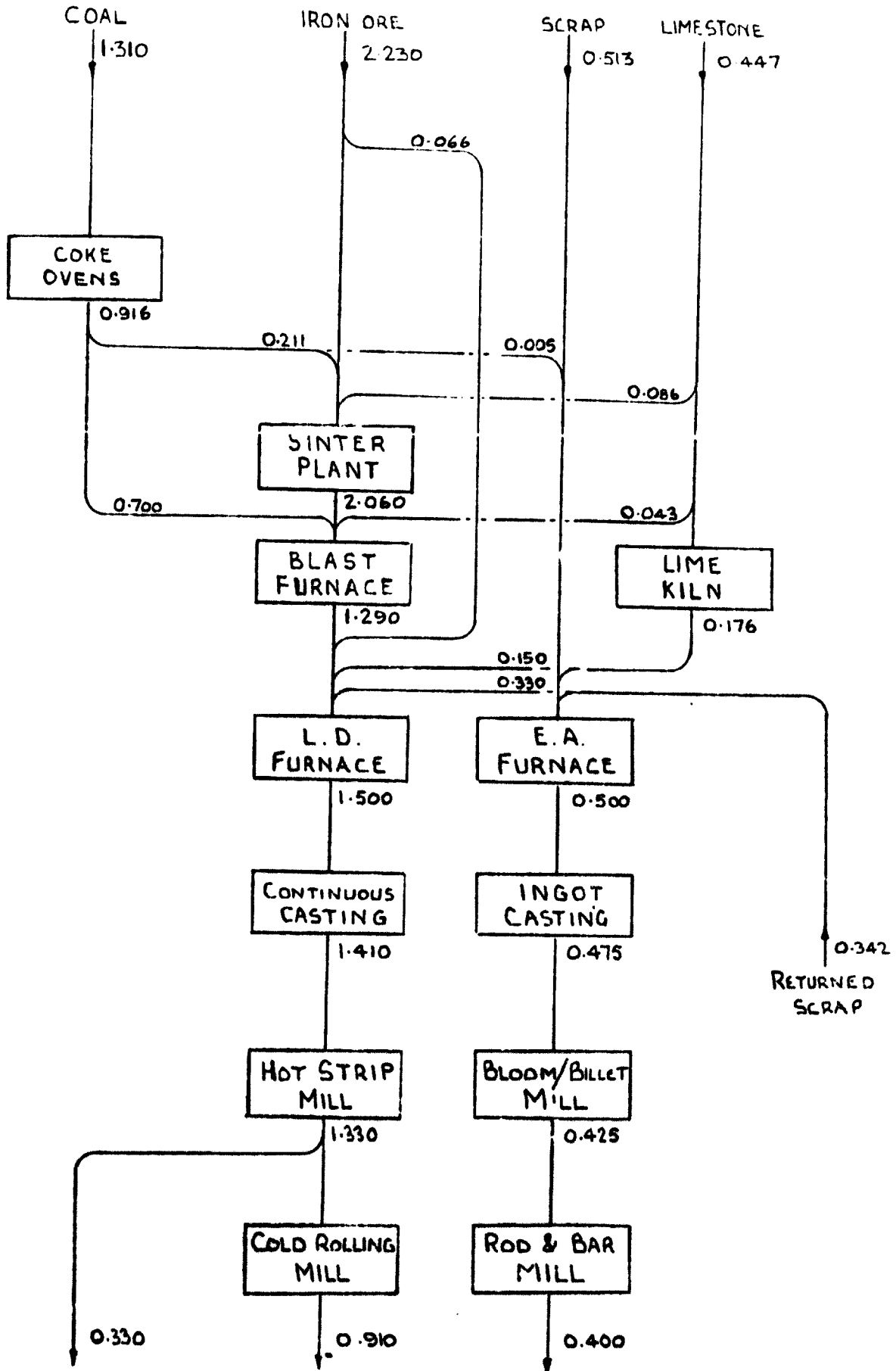
ROD & BAR MILL

0.330

0.910

0.400

Figure 2 (All figures in millions of tonnes per annum)

NOTIONAL INTEGRATED IRON & STEELWORKS

ALL FIGURES - M.T.P.A.

TABLE 1

Model Coking Plant (2700t of dry coke/day)

(a) Air pollution - in the form of gases and solid particles emitted into the atmosphere either directly or via the exhaust outlets of the coke plant ventilation and extraction systems.

Pollutant	Emission level kg/t dry coke	Annual Model tonnages
Coal and coke dust	2.0	1830
Coke oven gas	0.7 ($\sim$0.4 Vol.% of total gas make - 300m^3/t coke)	641
SO_2	0.63	577
H_2S	0.12	110
Phenols	0.13	119
Aromatics	0.21	192
HCN	0.07	430
NH_3	0.14	128
Pyridine bases	0.02	18

(b) Water pollution - arises from oven gas cleaning, coke quenching and byproduct separation and consists of solids in suspension plus chemicals in solution. Below are shown the pollutants that enter the wash water used before reaching the byproduct plant (ammonia and benzole recovery).

Suspended solids	10.0	9200
Phenols	0.33	300
NH_3	4.0 (97% of that in the gas)	3700
Cyanides	0.014	13
Thiocyanate	0.11	100
Chlorides	1.6	1460
Permanganate	1.8	1650

Total wash water quantities are normally $\sim$20t/t coke and bleed off 0.4t/t coke. Efficient treatment plants will remove from the water virtually all the suspended solids, phenols, ammonia, cyanides, thiocyanate and permanganate contents at least to a residual level acceptable for discharge to the local drainage system.

TABLE 2

Iron and Steelworks
Approximate Process Losses

Raw Materials	% Input	% Recoverable
Wind Losses and Non-recoverable Spillage	0.25	0
Handling, Crushing and Screening		
Wind Losses	0.5	0
Segregated Spillage	0.5	100
Coke Ovens	**% Output**	
Charging, Pushing and Quenching Dust	0.2	0
Sinter Plant		
Feed Materials Spillage and Dust	1.0	95
Exhaust Fume Dust	1.75	90
Sinter Spillage and Dust	1.25	95
Blast Furnace	**% Iron Output**	
Feed Materials Dust	1.0	90
Furnace Gas Dust	2.0	90
Slag Iron Loss	0.5	0
LD Steel Furnace	**% Steel Output**	
Fume Exhaust Dust	2.0	99*
Slag Steel Loss	3.0	30
Electric Arc Furnace		
Fume Exhaust Dust	0.4	99
Slag Steel Loss	2.0	30
Hot Rolling Processes		
Mill Scale	1.5	75

TABLE 3

Typical Circulating Water Requirements

for the Model Iron and Steel Works

Process centre	Output (mtpa)	Circulating Water	
		Tonnes per tonne of output	Millions tonnes for model works
Coke ovens	0.916	20	18.32
Lime Kiln	0.176	7	1.225
Blast Furnace:			
- cooling	1.29	25	32.25
- gas cleaning		15	19.35
L.D. Plant	1.5	7	7.5
Electric Arc Plant	0.5	7	3.5
Casting	1.885	18	33.93
Rolling			
- Mill cooling	1.64	20	32.80
- Furnace & Motor Cooling		10	16.40

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