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UNIDO

Project No TF/HUN/94/E90

Reduction of Air Pollution at Dunaferr Steelworks, Hungary

Final Report

Confidential
April 1997

CONTENTS

MANAGEMENT SUMMARY

MANAGEMENT SUMMARY

This Final Report has been prepared by McLellan and Partners Ltd (McLellan) in accordance with the requirements of Clause 2.07(b) of UNIDO Contract No.95/209/VK and the subsequent Contract Amendment No.1 to carry out a Design Study into the reduction of air pollution arising from the basic oxygen steelmaking plant at the Dunaferr Steelworks Company in Dunaújváros, Hungary.

The majority of the fume generated during the blowing phase of the oxygen steelmaking process is captured and cleaned satisfactorily by the existing primary fume cleaning system. The principal sources of air pollution at the steel plant are the intermittent secondary fume emissions from the LD Converters, the "Scan Lance" unit, the hot metal Mixer and the slag Rabbling Station. The periodic emissions of secondary fume from these sources rises to the top of the steel plant building and escapes through the roof to the outside atmosphere as an intermittent dark cloud of particulate pollution, as shown on Plate 5 in Annex 5.

The secondary fume is generated by oxidation of molten metal and impurities, particularly during Converter charging and, to a lesser extent, during oxygen blowing, tapping of liquid steel, de-slagging, transfer of hot metal to and from the Mixer and operation of the Scan Lance unit. Typical examples of these secondary fume emissions are illustrated in Plates 1 to 4 in Annex 5.

The proposed new air pollution control system will capture and clean the secondary fume emissions from the LD Converters and "Scan Lance" unit in a new bag filter plant.

Since the hot metal Mixer and slag Rabbling Station are already equipped with a fume extraction system and bag filter plant to control the air pollution from these sources, it is recommended that the existing system is upgraded to operate satisfactorily. The

alternative of capturing and treating the fume from these sources in the proposed secondary fume cleaning system of the LD Converters would not be cost effective and there would be difficulty in routing the interconnecting ductwork.

The majority of the secondary fume from each LD Converter will be captured by a dual extraction, low level refractory lined hood, located above the mouth of the Converter, when the vessel is in the charging position as shown in Figures 2, 4 and 5 of Annex 4. The effectiveness of the low level fume extraction hoods will be enhanced by improved sealing of the existing partial enclosures around the Converters. Fume from the Scan Lance metallurgical treatment facility will be extracted from the rear port in the roof of the unit and mixed with the secondary fume from the Converters, prior to cleaning in a new bag filter plant.

A small proportion of the secondary fume from the Converters will not be captured by the low level extraction hoods and will rise to the roof of the lance aisle. To prevent this fume escaping from the steel plant building, the ventilation louvres in the roof above the Converters will be sheeted over and the fume will be extracted from the roof by ductwork connected to the new bag filter plant. Ventilation and removal of heat from the steel plant building will be achieved by a combination of the new secondary fume extraction system, the remaining openings in the roof and other openings in the building.

In developing the design of the secondary pollution control system, the following options have been considered, which are based on different design criteria:

Option 1 - Figure 1.1:

This option permits extraction of secondary fume from the Converters and the roof of the steel plant building with both Converters operating simultaneously. This so called "2/2" option minimises potential future constraints on the operation of the steel plant by the secondary fume collection system and is considered to match the current best world standards.

Option 2 - Figure 1.2:

This option is based on full low level extraction of fume during the operation of one Converter only and extraction from the sealed roof space of the building over an extended period. This so called "2/1" option represents a "low cost" alternative to Option 1.

The proposed capacity of the new bag filter plants associated with each option would permit the following maximum extraction rates:

Option 1:	1 200 000 Am^3/h
Option 2:	735 000 Am^3/h

The extracted volume will be divided between the low level hoods, roof extract points and Scan Lance. The control of extraction volumes will be by dampers, automatically positioned according to a combination of steelmaking conditions and measurement of the fume concentration.

The proposed configuration of the new secondary fume extraction system and bag filter plant for both alternative options is shown in Figures 1 to 6 of Annex 4.

Because of the physical constraints imposed by the existing equipment and structures within the steel plant building, the proposed routing of the inter-connecting ductwork between the low level hoods and the bag filter plant is not ideal but will be acceptable. The fume extraction will be provided by high efficiency centrifugal fans; preferably driven by variable speed motors, to minimise the consumption of electricity.

The capacity of the proposed secondary fume control system would allow Dunaferr Steelworks to connect additional metallurgical treatment plant, such as a ladle furnace, to the secondary fume extraction system at some future stage; particularly in the case of the more generously sized Option 1.

The particulate content of the waste gases discharged to atmosphere from the stack(s) of the secondary fume cleaning system will be less than 15 mg/Nm^3 and will be continuously monitored by opacity meters. It is anticipated that dust levels within the steel plant building will be reduced to < 5 mg/Nm³. These particulate levels are consistent with the current "Best Practice" achieved in Western European steel plants.

Based on manufacturers' budget quotations for the major items of equipment and cost estimates of the other elements of the work, it is estimated that the capital cost of the alternative secondary fume control options will be as follows:

Option 1:	US$7 746 000
Option 2:	US$5 027 000

At present, no allowance is included in the cost estimates for upgrading the existing fume collection and cleaning system serving the Mixer and Rabbling Station, since these costs should be relatively modest and would normally be regarded as either development expenditure for plant optimisation or considered to be part of the maintenance budget.

The choice between Option 1 and Option 2 will be strongly influenced by the availability of funding at the Dunaferr Steelworks and the competition for the available financial resources from other potential investments within the steelworks.

Option 1 would permit full secondary fume extraction with 2 LD Converters operating simultaneously and offers the greatest flexibility to accommodate additional future sources of fume within the steel plant, such as a Ladle Furnace or other metallurgical treatment facilities.

If Dunaferr Steelworks wishes to minimise expenditure on secondary fume control, Option 2 would be a satisfactory alternative solution. However, this arrangement offers less flexibility to operate 2 LD Converters simultaneously and there would be less capacity available to cater for additional future sources of fume. The longer retention time of the fume in the roof space above the Converters will also increase the risk of higher drop-out of particulate material within the steel plant building and lead to higher temperatures in the upper levels of the building, compared to Option 1.

SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

This Report has been prepared according to the requirements of the undernoted Contract between The United Nations Industrial Development Organisation (UNIDO) and McLellan and Partners Ltd (McLellan):

Contract No 95/209 and supplemental Contract Amendment No. 1
(UNIDO Project No TF/HUN/94/E90)
"Reduction of Air Pollution at Dunaferr Steelworks in the Republic of Hungary"

The Contract principally concerns a Design Study of the pollution control of secondary fume emitted at the LD Converters, and the existing Scan Lance refining station of the steelmaking plant at the Dunaferr Steelworks in Hungary.

At present, there is no control of the secondary fume emitted from the LD Converters. Hence, there are regular emissions of visible fume from the roof of the steel plant building (Annex 5, Plate 5) and within the steel plant there is a dust nuisance in terms of both airborne and deposited dust. The dust, which consists mainly of iron oxide and carbon (kish) can create health and safety risks and is a source of maintenance problems.

Throughout the European steel making industry, and specifically at Dunaferr, there is considerable pressure to reduce atmospheric pollution. An improvement in the quality of the working environment will reduce pressure on Dunaferr from the workforce, the local community and the environmental regulatory authorities.

However, the installation and subsequent operation of a secondary fume cleaning system is costly. It is therefore important that the design is optimised and makes cost effective provision to meet predicted future plant demands, whilst also meeting anticipated future changes in environmental legislation.

The Design Study has been undertaken in two stages. In the first stage, a visit was made by McLellan to the Dunaferr steelworks to gather information on the layout and operation of the plant and take measurements relating to the sources of fume within the steel plant. This information, together with data supplied by Dunaferr, formed the basis of the subsequent work.

After the initial visit, an Interim Report was submitted to UNIDO outlining potential alternative solutions to the problem of air pollution at the steel plant. From these alternatives, a number of options were examined and the optimum process route selected.

This Final Report outlines the technical issues and the two alternative design options that have been considered in detail.

Section 2 of the Report summarises the environmental standards to be achieved to match the current best Western European practice and defines the basis of the two alternative design options described in this Final Report. Sections 3 and 4 record the sources and volumes of the fume generated by the steel making operations at Dunaferr. Section 5 describes the design of the proposed options for secondary pollution control and Sections 6 to 10 summarise related information. Section 11 summarises the estimated capital and operating costs of the system and Section 12 contains an indicative programme.

Annex 1 discusses the existing secondary fume extraction system serving the Hot Metal Mixer and Slag Rabbling Station and proposes various measures to improve the effectiveness of the present pollution system.

Annexes 2 and 3 summarise the basic design criteria used in the study, including the derivation of the fume extraction volumes.

Annex 4 contains the drawings which form part of the study and Annex 5 includes photographs illustrating the sources of secondary fume.

McLellan wishes to acknowledge and thank both the Management and the Operating and Maintenance personnel of the Dunaferr Steelworks for the considerable cooperation and assistance received by McLellan throughout the Study.

SECTION 2

PERFORMANCE SPECIFICATION
FOR THE SECONDARY FUME CONTROL SYSTEM

SECTION 2

PERFORMANCE SPECIFICATION FOR THE SECONDARY FUME CONTROL SYSTEM

The performance specification stipulated by UNIDO requires the new secondary fume control system to achieve environmental standards comparable with the best practice achieved in steel plants in Western Europe.

2.1 WESTERN EUROPEAN ENVIRONMENTAL STANDARDS

2.1.1 Atmospheric Emissions

Basic oxygen steel plants within Western Europe that have installed or are installing secondary fume control equipment typically aim to achieve the following emission limits:

- Stack discharge < 15 mg/Nm^3
- Roof discharge < 15 mg/Nm^3

These levels of emission to atmosphere can be regarded as current "best world practice" and, if achieved at Dunaferr, should comply with any likely future environmental legislation within Hungary.

The above environmental performance criteria was the design basis of the preliminary pollution control schemes listed in the Interim Report presented by McLellan to UNIDO in February 1996 and is the criteria to be achieved by the design proposals contained in this Final Report

2.1.2 Workplace Emissions

The typical limits for dust concentrations in the workplace within UK steelworks are:

- 10 mg/m^3 Total inhalable dust (8 hours/day)
- 5 mg/m^3 Total respirable dust (50 hours/week)
- 30 mg/m^3 Total inhalable dust (10 minutes weighted average)

"Total inhalable dust" approximates to the fraction of airborne material which enters the nose and mouth during breathing and could deposit in the respiratory system. "Respirable dust" approximates to the fraction which penetrates to the main surface of the lung.

These limits are based on the UK Occupational Health Regulations that are typical of those in force in Western Europe.

2.2 LD CONVERTER OPERATION

Dunaferr Steelworks currently operate only one of the two LD Converters at a time; the other vessel either being relined or on standby. This operating mode is known as *"2/1 operation"*.

However, Dunaferr Steelworks have indicated that, in the future, they may wish to operate both LD Converters simultaneously. For the purposes of this report, this potential future operating regime is referred to as *"2/2 operation"*.

Dunaferr Steelworks have stipulated that the new secondary fume cleaning system must also be capable of accommodating the fume arising from the possible future installation of additional metallurgical treatment facilities, such as a Ladle Furnace, within the steel plant.

2.3 DESIGN OPTIONS

Based on the design criteria described above, the following alternative design options have been developed for the proposed secondary fume cleaning system at the Dunaferr steel plant:

OPTION 1: Permitting simultaneous operation of 2 LD Converters, together with the Scan Lance unit and rapid extraction of fume from the sealed rood space above the converters.

OPTION 2: Allowing the operation of 1 LD Converter at a time, together with the Scan Lance unit and extraction of fume from the sealed roof space over an extended period.

Option 1 is consistent with current best world practice and gives the greatest future flexibility. Option 2 offers a lower cost solution to the present problems of secondary air pollution, which may be more compatible with the financial constraints of the Dunaferr steelworks than the more expensive Option 1.

SECTION 3

SOURCES OF SECONDARY FUME IN THE LD CONVERTER SHOP

SECTION 3

SOURCES OF SECONDARY FUME IN THE LD CONVERTER SHOP

The main sources of secondary fume within the existing oxygen steelmaking plant are:

i) LD Converters
ii) Scan Lance Refining Station
iii) Hot Metal Mixer
iv) Slag Rabbling Station

At some future stage, Dunaferr Steelworks may wish to install additional metallurgical treatment facilities, such as a ladle furnace. The proposed new secondary fume control system for the LD Converters will be designed to accommodate the additional fume from such new plant. The hot metal Mixer and Slag Rabbling Station are already served by an existing independent fabric filter fume cleaning system and are outside the scope of this study. However, the present performance of this independent fume cleaning system is not satisfactory and so, for completeness, suggested improvements to this system are discussed in Annex 1.

3.1 LD CONVERTER FUME GENERATION

Secondary fume is generated at each of the following stages in the production cycle of the LD Converter:

i) scrap charging
ii) hot metal charging
iii) oxygen blowing
iv) tapping and
v) de-slagging.

The characteristics and extent of the secondary fume generated at each of the above production stages are discussed below.

3.1.1 Scrap Charging

The amount of secondary fume generated during charging of scrap into an empty converter is relatively minor, with "puffs" of fume emitted from the Converter mouth due to the displacement of air and the combustion of organic impurities in the scrap.

3.1.2 Hot Metal Charging

On commencement of charging the Converter with molten iron ("hot metal"), high temperature fume is generated due to oxidation of the stream of molten metal and the combustion of carbon monoxide gas. The resulting high velocity flames engulf the ladle mouth of the charging ladle and extend to about 8m above the mouth of the Converter. This phenomenon is shown on Plate 1 in Annex 5. The fume has high thermal buoyancy and rises close to the main primary hood before being deflected by the structural beam supporting the main water cooled ductwork above the charging floor. The fume has sufficient thermal buoyancy to travel up through the building, without significant dispersion and it eventually discharges to the outside air as a dark plume through the ventilation louvres in the roof of the steel plant building.

As charging continues and the angle of the pouring ladle increases, the flow of fume is disturbed by the ladle causing the entrainment of ambient air. This air entrainment reduces the temperature of the fume and decreases its buoyancy. These conditions reduce the fume velocity and create a greater tendency for the fume to disperse into the front of the charging bay.

The following factors influence the evolution of fume during charging of the Converter with hot metal:

- entrained air, which enters the Converter with the molten iron and oxidises the charge to produce CO, CO_2 and metallic oxides
- releases of flakes of graphite (kish) due to cooling of the molten iron

- iron oxide scale on scrap reacting with molten iron

- combustion of organic impurities mixed with the scrap.

Important variables that affect the rate of fume evolution include:

- the rate of charging hot metal
- scrap composition; (Fe_2O_3, oil, moisture, bulk density)
- hot metal composition; (particularly carbon and silicon content)
- hot metal/scrap ratio
- amount and composition of slag retained in the vessel after tapping
- amount of slag retained in the hot metal charged to the Converter
- iron temperature.

Deviation from good operating practices can increase the amount of fume generated, particularly if the hot metal is charged too quickly. Observations at Dunaferr indicated that all the above factors are within the common industry norms. The maximum charging rate of hot metal is typically 1.0 - 1.5 tonnes per second, which is lower than the pouring rate of 1.5 - 2 tonnes per second typically used in Western European steelworks for larger converter vessels.

3.1.3 Oxygen Blowing

During oxygen blowing, most of the fume is captured and cleaned by the primary fume extraction system, with little escape of secondary fume. However, at the start of a Converter campaign, when the refractory lining is new and the level of the molten metal is therefore high, "slopping" of the molten metal can occur during the peak of the oxygen blow. During this period "puffs" of fume can escape from the annular gap between the mouth of the Converter and the extraction hood of the primary fume collection system. This fume disperses into the building as shown in Plate 2 of Annex 5. The fume typically has a relatively high dust loading, though the volume of fume generated is low.

3.1.4 Tapping

When the Converter is tilted forward for tapping the molten steel into a ladle, a considerable amount of secondary fume rises from the tapping ladle. Because of it's temperature, the fume is buoyant and rises around the sides of the Converter. Due to the "front tap" procedure used at Dunaferr, most of this fume rises past the structural beam supporting the waste heat boiler. At this point the fume is deflected into the front of the charging floor bay, where it mixes with ambient air. The fume has sufficient thermal buoyancy to rise to the roof ventilator of the lance aisle and escape from the building. Some of the fume generated during tapping escapes through various gaps in the partial enclosure around the Converter and rises through the building before escaping to the outside atmosphere through the roof ventilator of the lance aisle. Typical examples of the fume generated during tapping are shown on Plates 3 and 4 in Annex 5.

3.1.5 De-Slagging

At the end of tapping steel, the slag retained in the Converter is poured out of the Converter into a slag pot by a "rear tap" procedure. There is not a significant amount of fume produced during this operation, though it has sufficient velocity and buoyancy to rise through the building and escape to the atmosphere through the lance aisle roof ventilator.

3.2 SCAN LANCE FUME GENERATION

The molten steel tapped from the LD Converter is transferred to the Scan Lance unit in a ladle, where the steel is refined by blowing oxygen through a lance and making various alloy additions.

This secondary metallurgical treatment creates fume, which escapes from the Scan Lance enclosure through the lance opening and the extraction port at the rear of the roof which, is at present, dis-connected from the fume discharge system.

SECTION 4

QUANTITY OF SECONDARY FUME GENERATED IN THE LD CONVERTER SHOP

SECTION 4

QUANTITY OF SECONDARY FUME GENERATED IN THE LD CONVERTER SHOP

4.1 VOLUME OF LD CONVERTER SECONDARY FUME

The amount of secondary fume generated during steelmaking operations is variable and its volume is influenced by the extent of mixing and dilution with ambient air. The following section of the report summarises the estimated quantities of secondary fume generated at each stage of the LD Converter production cycle.

4.1.1 Scrap Charging

The peak fume velocity at the mouth of the Converter during scrap charging was estimated to be approximately 2 m/s. The maximum temperature of the secondary fume during scrap charging has been measured as 250°C. These figures give a fume flow rate of around 18.2 Actual m^3/s (Am^3/s). It is considered that the extraction rate of the fume collection system to capture this fume should be approximately 3.5 times the calculated rate of fume emission.

This factor, which is typical of Western European practice, gives a total extraction rate of 195 700 Am^3/h at 75°C.

Observations at site showed that the dust loading of the secondary fume during scrap charging was minimal and a nominal figure of 0.5 g/Nm^3 has been used for calculation purposes. This results in a collected fume dust loading of around 0.1 g/Nm^3.

4.1.2 Hot Metal Charging

Most of the fume generated during hot metal charging can be assumed to originate from the Converter mouth. The peak fume velocity near the mouth of the Converter was estimated to be around 8 m/s, at a recorded peak temperature of approximately 1 000°C.

This high temperature is due to the combustion of carbon and carbon monoxide during the charging of hot metal.

The maximum diameter of the mouth of the LD Converters used at Dunaferr has been estimated to be approximately 3.4m, after wear of the refractory lining. On the basis of the above figures, the maximum fume generation is estimated to be around 72.6 Am^3/s at 1000°C (15.6 Nm^3/s). Based on observations at Dunaferr and data obtained from other operating plants, the fume dust loading of the secondary fume during hot metal charging (undiluted) has been estimated to be around 25 g/Nm^3 .

After discharging from the mouth of the Converter, the secondary fume rises and entrains ambient air from the surroundings. The amount of air entrained in the fume can be assessed from video recording of the plume, together with typical extract duct temperatures and air flows at other operating plants. Plant data and operating practice show in-duct mixed gas temperature of 250°C. On this basis, to achieve this mixed gas temperature, an extraction volume of 129.3 Am^3/h is required. This is equivalent to an extraction flow rate of 465 000 Am^3/h at 250°C.

For the Dunaferr steel plant to match current world standards, approximately 80% of this fume should be collected by the low level hood, requiring an extraction rate of around 372 500 Am^3/h at 250°C. An extraction dust concentration of 7.2 g/m^3 is taken for design purposes.

4.1.3 Oxygen Blowing

Measurement of the actual volumes of secondary fume due to "puffing" during the oxygen blowing phase is difficult. On similar plants, it has been estimated that "puffing" accounts for up to 5% of the total primary off-gas volume. In view of the limited observance of "puffing" at the Dunaferr LD Converters, it has been estimated that less than 2% of the primary gas flow will escape the primary fume extraction system. This fume has a low velocity and it has been estimated that the maximum is around 5 m/s. The fume escapes from the annular gap between the base of the primary fume extraction system and the mouth of the converter. The area of this annulus is approximately 7m^2 , resulting in a theoretical maximum fume flow of around 126 000 Am^3/h, at an estimated temperature of approximately 300°C. This is equivalent to a flow of around 60 000 Nm^3/h.

Due to its low velocity, the above secondary fume mixes rapidly with the ambient air before reaching the structural beam supporting the waste heat boiler plant. The amount of air entrained in the fume is uncertain, although data from other sources indicate that the extraction volume necessary to collect "puffing" fume is approximately 1.2 times the fume volume. Due to the uncertain nature of "puffing", a margin has to be included for the worst conditions, such as low freeboard above the molten metal when the refractory of the Converter is new. With this design margin, the required extraction rate is estimated to be around 205 000 Am^3/h at a temperature of 150°C. On this basis, the dust concentration of the mixed secondary fume has been estimated to be approximately 6.8 g/Nm^3.

Although the above extraction flow is only theoretically required during the escape of "puffs" of fume from the primary fume collection system, the onset and extent of this phenomenon cannot be accurately predicted. Therefore the extraction will be required during the complete blowing operation.

4.1.4 Tapping

Based on measurements taken at Dunaferr and information from other steel plants, it is estimated that the maximum fume velocity from the mouth of the ladle during tapping is around 8 m/s at 200°C. The cross sectional area of the tapping ladles used at Dunaferr is approximately 4.5m^2. On the basis of these figures, the fume generation during tapping has been calculated to be around 36.0 Am^3/s at 200°C (20.8 Nm^3/s). Observations during the operation of the plant indicated that the dust loading during tapping was low. A notional dust concentration of 15 g/Nm^3 has been used in this assessment, which is typical for the industry.

As the fume rises past the Converter towards the proposed low level extraction hood, ambient air will become entrained. Figures from other plants show that the typical in-duct temperature of the tapping fume is approximately 120°C. Based on a secondary fume flow of around 20.8 Nm^3/s at 200°C from the mouth of the ladle, an extraction rate of 38.3 Nm^3/s is required, which is equivalent to 198 400 Am^3/h at 120°C. Consequently, a nominal flow of 200 000 Am^3/h at 120°C is required, with a design dust concentration of around 8.1 g/m^3.

4.1.5 De-Slagging

Observations at Dunaferr indicated a peak fume velocity during de-slagging of 3.5m/s. Based on the area of the slag pot mouth of 6.16m^2, this equates to a fume generation rate of around 21.6 Am^3/s or, at a measured peak fume temperature of 100°C, 15.8 Nm^3/s.

At Dunaferr, the Converter is tilted away from the charging floor during de-slagging. Due to this orientation, the secondary fume generated during de-slagging has limited vertical "escape" routes and the fume travels by different routes around and over the Converter. Consequently, the fume is widely dispersed before leaving the vicinity of the converter and thus the extraction volume required is difficult to estimate. It has been empirically estimated that an extraction rate of roughly half the fume volume is required for complete extraction of this fume.

This results in an extraction rate of around 109 000 Am^3/h at 75°C.

The dust loading of the secondary fume during de-slagging is very variable and is influenced by a number of factors, particularly the slag characteristics. Observations at site showed that the slag characteristics and associated dust loading of the fume was typical of a Western European steelworks. Based on typical data from such sources, the de-slagging fume dust loading has been taken as 3 g/Nm^3, giving a collected design fume dust loading of 2 g/Nm^3.

4.2 SCAN LANCE

Based on estimates made at Dunaferr and information from similar steel plants, the maximum velocity of the fume escaping from the opening in the Scan Lance enclosure is estimated to be around 10m/s at 1000°C. The combined cross sectional area of the lance port and rear port around is approximately 0.4m^2. Based on these estimates, the fume generation has been calculated as 4.0 Am^3/s at 1000°C; (equivalent to 0.84 Nm^3/s or 31 500 Am^3/h). Observations at Dunaferr and information from other steel plants indicate that the typical dust loading during blowing is approximately 25 g/Nm^3 and this has been used to estimate the extracted dust loading of around 5.8 g/Nm^3.

4.3 ROOF EXTRACTION

The fume extraction at roof level is designed to capture the fume which is not collected by the low level extraction hoods and other minor sources of fume within the steel plant. The roof level extraction system is also designed to provide sufficient building ventilation to replace the natural ventilation lost by the proposed sealing of the roof louvres.

Based on the typical efficiency of conventional low level extraction hoods, it is reasonable to assume that up to 20% of the fume generated during hot metal charging of a Converter will not be captured by the low level hood. On this basis, the volume of secondary fume escaping the low level hood during charging of a Converter at the Dunaferr Steelworks is estimated to be around 93 100 Am^3/h at approximately 1000°C.

As the fume rises through the building, the temperature of the fume reduces due to ambient air entrainment and is typically around 100°C at the roof monitor. This equates to a total fume volume of approximately 354 700 Am^3/h at 100°C.

In the case of the generously sized Option 1, which permits simultaneous operation of 2 Converters, the roof extraction rate has been selected to match the estimated rate of accumulation of secondary fume in the roof space. This results in an extraction rate of around 355 000 Am^3/h at 100°C.

In Option 2, in order to reduce the capacity (and hence cost) of the fume extraction system, it is proposed to allow a proportion of the hot fume to temporarily accumulate in the roof space of the lance aisle. The fume will then be extracted over a nominal period of around 4 minutes. By adopting this design philosophy, it is possible to reduce the roof extraction rate to around 177 300 Am^3/h at 100°C. However, this lower extraction rate compared to Option 1 increases the risk of drop-out of the heavier particles of fume and could lead to higher temperatures in the upper levels of the building.

In both cases, the extraction from the roof space would be controlled by an obscuration monitoring instrument in order to conserve energy.

Sealing of the roof space to prevent the escape of fume to the atmosphere will disrupt the natural ventilation of the steel plant building. The heat emitted by the molten metal raises the temperature of the ambient air in the building, creating a convective air flow, which under normal circumstances leaves the building through the ventilators in the roof. Without sufficient natural ventilation, the ambient air temperature within the building will increase. In the case of the Dunaferr steel plant building, when the lance aisle roof is sealed, the remaining roof ventilators, combined with the open nature of the building and the roof extraction system, should provide adequate ventilation.

4.4 COOLING AIR BLEED

In order to protect the proposed bag filter material against peak transient temperature excursions above the design limit of 130°C, an emergency cooling air bleed, controlled by a damper, will be provided upstream of the bag filter plant.

In the case of Option 1, the theoretical maximum air bleed would be around 210 000 Am^3/h and for Option 2 would be approximately 202 000 Am^3/h.

In the event of the cooling air bleed being insufficient to control the maximum temperature into the bag filter plant, the exhaust fans will be tripped and dampers closed to protect the filter bags.

4.5 SUMMARY OF FUME EXTRACT VOLUMES

Annex 3 summarises the estimated fume extraction volumes, dust loadings and fume temperatures during the simultaneous operation of two Converters [i.e. Option 1] and for single Converter operation [i.e. Option 2].

SECTION 5

DESIGN OF THE SECONDARY FUME CONTROL SYSTEM

SECTION 5

DESIGN OF THE SECONDARY FUME CONTROL SYSTEM

The proposed secondary fume control system will comprise the following four main elements:

i) Fume collection system from the LD Converters
ii) Fume collection system from the Scan Lance unit
iii) Fume extraction from the building roof
iv) Treatment plant to clean the fume prior to discharge to atmosphere

The secondary fume from the LD Converters will be mainly captured close to its source by extraction through the low level hoods. The hoods will be designed to collect > 95% of the secondary fume during most operations but during hot metal charging, the fume volume is particularly large and a collection efficiency of around 80% is envisaged. The fume that is not captured by the low level extraction system will rise to the roof ventilator of the lance aisle. Fume collection from the Scan Lance unit will be through the existing rear port of the Scan Lance roof.

All the fume collected from the above sources will be ducted from the steel plant to the dust removal equipment located adjacent to the steel plant building.

5.1 LD CONVERTER FUME COLLECTION

5.1.1 LD Converter Low Level Hoods

The secondary fume from the operation of each LD Converter will be collected by a low level extraction hood positioned on the charging side of each Converter. The proposed location of the dual extraction low level hoods and their associated ducting is shown in Figures 2, 4 and 5 of Annex 4.

During charging of the Converter, the secondary fume rises directly upwards and the majority will be captured by the proposed low level hood. Fume generated on the opposite side of the Converter during de-slagging, rises at the rear of the existing partial enclosure around the Converter. With the present arrangement, most of the fume from the de-slagging operations escapes from the partial enclosure and flows upwards on both sides of the Converter vessel into the roof ventilator of the lance aisle.

The space available on the de-slagging side of each Converter vessel is extremely limited and any local hood arrangement to capture the fume on this side would require substantial re-engineering of the existing structures and equipment.

By selective sealing of the rear of the existing Converter enclosures, the de-slagging fume can be directed towards the front side of the vessel to be captured by the proposed low level fume extraction hood. This arrangement will avoid the need for a separate extraction hood for de-slagging fume.

In ideal circumstances, the most suitable type of low level extraction hood would be a "canopy type", situated directly above the mouth of the Converter. However, the geometry and position of the canopy hood to capture secondary fume during charging and de-slagging is severely restricted by the crane movements during charging. This is particularly true of the horizontal depth of the face of the hood.

The horizontal depth of the hood face will be the maximum permitted without interfering with the crane approach. Modifications to the design of the crane hook to facilitate hood design are not practical and so the low level hood must be designed to minimise the risk of impact from the existing crane hook assembly, charging ladle or scrap chute. The risk of crane / hood collisions however, cannot be entirely removed and so the hood should be designed to be easily replaced at minimum cost and should last at least one full campaign without refurbishment. Some installations have adopted a hinged hood, which can swing under impact from the crane, thus minimising damage.

Each Converter will have extraction from both ends, to ensure that the fume is collected across the whole face of the hood. Experience has shown that where single point extraction at the centre or end of the hood is used, the extraction is not evenly distributed. This mal-distribution can be improved by fitting deflectors or vanes inside the hood but such devices are vulnerable to deformation, hinder maintenance and are rarely completely successful.

To ensure that fume which does not flow naturally into the hood is captured, the face velocity at the hood inlet must be substantially greater than the natural velocity of the fume. However, to minimise the ingress of excessive volumes of ambient air, the length of the face of the hood will be marginally more than the width of the rising plume of fume.

Potential options to improve the capture of secondary fume by the hood, such as chains and air curtain hoods, have been considered but are deemed to be impractical due to the presence of the charging crane and ladle.

Measurements at other steel plants have shown that short-term peak transient temperatures up to 1 200°C can be experienced by low level charging hoods. However, normally the low level hood extracts a mixture of high temperature fume, together with substantial quantities of ambient air. Whilst this ambient air has a significant cooling effect on the extracted fume (eg 250°C), experience has shown that short-term peak hood temperatures of up to 1 000°C are common. The cyclic thermal stresses experienced by the low level hood during the operating sequence of the LD Converter can lead to deformation and thermal cracking of the hood, if it is not well designed.

Various types of hood design have been employed to withstand the above arduous conditions, including the concept of a "consumable" hood fabricated from mild steel plate. However, the latter type of simple hood typically only has a lifetime of one campaign, and is thus considered un-economic.

The cheapest method of protecting a mild steel hood from the effects of large temperature fluctuations is to refractory line the hood. The refractory linings can be cast or gunned in place, with a recommended minimum thickness of around 70 mm to ensure mechanical strength. The refractory should be capable of withstanding short term peak temperatures of 1 200°C and typical maximum transient temperatures of up to 1 000°C. The refractory must be erosion resistant to with stand the abrasive nature of the dust in the fume, and should be capable of tolerating the thermal shock associated with the periodic rapid temperature fluctuations.

Refractory lining the hood has the disadvantage that it is susceptible to mechanical damage if there is impact between the crane and the hood. This risk can be minimised by installing a robust structural steel "bumper" above the hood to limit the horizontal approach of the crane spreader beam. The extent of mechanical damage to the refractory can also be reduced by using refractory materials strengthened with stainless steel needle additions and the use of gunned refractory material simplifies any repairs. Another disadvantage of refractory lined hoods is that the refractory increases the wall thickness significantly. Since the minimum thickness of the refractory is probably around 70 mm, this can result in a significant reduction of the internal flow area available for fume extraction.

The most sophisticated and expensive option is to use a water cooled hood. Whilst this arrangement protects the hood against high temperature, it has a number of drawbacks. Water cooled hoods are expensive, require a significant amount of ancillary equipment and can lead to the risk of water leaks, which would be particularly dangerous in the context of hot metal charging.

A potential alternative water cooled option, which is theoretically cheaper, involves "air mist" cooling. In this process, fine droplets of water are sprayed onto the outside surface of the hood from air/water nozzles. As the water mist impacts the wall of the hood, it is evaporated producing a cooling effect. However, at the present time, McLellan is unaware of any installations using an air-mist cooled hood and therefore does not recommend this approach.

For the purposes of this Design Study, it has been assumed that the low level extraction hoods will be refractory lined.

As previously stated, the face velocity of the extraction hood should be higher than the fume velocity. However, this high face velocity can create a considerable amount of turbulence and corresponding noise. The noise is most noticeable in the vicinity of the hood face but can sometimes manifest itself at downstream duct surfaces.

In extreme circumstances, the noise created by the extract velocity can exceed 100 dB (A). However, the noise level can be controlled by limiting the velocity and smoothing the flow paths to reduce the turbulence. The noise level can also be attenuated by using thicker plate for fabricating the hood and using refractory insulation.

5.1.2 LD Converter Enclosure

Observations at the Dunaferr steel plant indicate that the provision of a full "doghouse" enclosure around each of the LD Converter vessels is impractical, due to the obstruction of the existing alloy addition systems and other charging floor equipment. The LD Converters are already equipped with partial enclosures. However, there is significant scope to improve the sealing of the existing enclosures, particularly on the de-slagging side and around the duct of the primary fume extraction system.

At present, the majority of the de-slagging fume escapes through the gap in the enclosure roof around the duct of the primary fume extraction system. Escape of fume from this source has also been observed during blowing operations. To increase the capture efficiency of this fume by the proposed low level hoods, selective sheeting should be provided.

Further areas that may benefit from additional containment sheeting are the sides of the tapping aisle underneath each Converter vessel. This will ensure that any fume from the tapping operations will rise to the low level hood and not be dispersed into the plant due to the effect of cross draughts from the natural ventilation of the building.

Sealing the Converter enclosures in the sampling floor area is difficult, due to the method by which metal sampling is carried out. However, observations during Converter operation indicate that fume escape from this source was minimal, suggesting that further sheeting in this area is probably superfluous.

5.2 SCAN LANCE

At the Scan Lance metallurgical treatment station, fume is generated during argon blowing and alloy additions. The fume generated escapes into the steel plant building through the lance hole in the tilting roof of the unit and, to a lesser extent, from the dis-used exhaust port at the rear of the roof.

In the proposed pollution control arrangement shown in Figures 1 to 6 of Annex 4, the fume generated during blowing at the Scan Lance will be extracted through the existing exhaust port at the rear of the roof. Collection of fume escaping from the lance port in the roof is difficult due to the position of the lance. To minimise fume escaping from this source, the size of the lance port could be reduced or, alternatively, the gap could be minimised by using a "lance port ring". The latter device is designed to allow full movement of the lance when it is being positioned but, during blowing, the annular gap around the lance is sealed.

5.3 ROOF EXTRACTION

To minimise the emission of fugitive fume from the steel plant building to the outside air and meet current best World standards, it is proposed that the ventilation louvres in the lance aisle roof are sealed and the fume collecting in the roof space is extracted by the fans of the bag filter plant.

The extraction volume from the roof space of the lance aisle is a significant proportion of the overall capacity of the secondary fume cleaning system. In order to conserve energy, it is recommended that extraction from the lance aisle roof space is only carried out when required. This can be achieved by continuously monitoring the fume concentration in the lance aisle roof space. "Long path" obscuration measuring instruments, which have been designed especially for this duty, have proved successful in controlling the extraction flow when linked to a damper in the extraction ductwork.

The detailed design of the roof extraction system will need to take the following considerations into account:

(a) The condition of the building sheeting in the lance aisle roof area could not be inspected in detail by McLellan but, based on preliminary inspection and considering the age of the plant, it seems likely that the sheeting will require some repair. Hence, apart from sealing the ventilation louvres to prevent the escape of emissions to the outside atmosphere, some local replacement of the existing sheeting may also be required to seal the building.

(b) The volume of the lance aisle roof space offers significant buffer storage for fume, which will help the roof extraction system to cope with deviations from the theoretical design conditions. In the case of Design Option 2, which is based on single Converter operation, the buffer storage of the roof space is utilised to enable the fume not captured by the low level hood during charging of the Converter to be extracted over a period of around 4 minutes.

In the case of Option 1, which is designed to cater for "2 Converter operation" and has more generous sizing of the fume cleaning plant, it is estimated that the lance aisle roof space will be cleared of charging fume in approximately 2 minutes. This will minimise the risk of drop-out of the heavier fume particles and provide greater ventilation of the roof space than Option 1.

(c) Figure 4 of Annex 4 shows the extraction will be from both ends of the lance aisle roof, with the ducts connected to the North West and North East sides of the roof. Both extract ducts will be provided with a flow damper, before combining into a single duct. The positioning of the ducts will be such that the maximum extraction is directly above the converter vessels.

The fume extract ductwork from the roof will be connected to the main secondary fume extraction system as shown on Figures 1, 3 and 4 of Annex 4.

5.4 DUCTWORK DESIGN AND ROUTING

5.4.1 Ductwork Design

In designing the inter-connecting ductwork to transport the captured fume to the dust removal equipment, the following factors have been taken into consideration:

(a) The type of duct can be either rectangular or circular in cross section. Where space permits, circular ducts have the advantages that they have lower relative pressure drop, are easier to install and require less bracing and stiffening. Rectangular ducts can be particularly useful where space restrictions, especially close to equipment, limit the use of circular ducts.

(b) The design of the inter-connecting ducting is based on a short-term transient peak maximum gas temperature of 350°C and a system pressure drop of 0.05 bar.

(c) As a precaution, the ductwork and associated mechanical support structures should be designed assuming a "worst case" hypothetical dust loading of 30% depth within horizontal ducts and a dust bulk density of 1 200 kg/m^3. For ducting located outside the steel plant building, snow and wind loadings should also be considered.

(d) Inspection hatches, with facilities for dust removal, should be provided at strategic positions.

(e) The pressure drop in the ductwork should be optimised.

(f) Duct design should minimise the number of points that are vulnerable to erosion by dust.

(g) Dampers are required for both flow control and isolation. All dampers should have appropriate maintenance access.

(h) The duct design is based on a maximum inflow leakage rate of 2%.

(i) The clearance between ducts and moving objects such as ladles should be greater than 100 mm.

5.4.2 Duct Routing

The routing of large diameter ductwork for retrofit installation within existing facilities is often difficult. This has proved to be the situation for the inter-connecting ductwork of the proposed secondary fume cleaning system at the Dunaferr steel plant, where the existing structures and equipment severely limit the space available. Consequently, the proposed duct routes described below are sometimes a compromise in order to minimise capital cost, structural alterations and potential disruption to production during the construction period.

(a) LD Converter Low Level Hood Ducting:

There are a limited number of options available for routing the extraction ductwork connected to the proposed low level secondary fume collection hoods of the LD Converters. The ducts cannot be routed directly upwards to the roof because of interference with crane movements and the alloy additions equipment prevents the ducts being routed sideways from the hoods. Some of the other alternative routes are limited by structural beams and the primary fume extraction equipment.

The most viable duct route from the low level hoods is initially vertically down through the charging floor to the space immediately below the floor. However, the clearance between the underside of the charging floor and the top of the tapping ladle is limited and, consequently, there are only two potentially feasible options for routing the ductwork through this space.

The first option, shown in Figure 2, involves routing all the ducts West under the charging floor. Due to the limited headroom above the moving tapping and de-slagging ladles, two separate fume extract ducts from the East Converter hood will be routed under the floor, together with one of the ducts from the hood of the West Converter, as illustrated in Figures 2 and 3 of Annex 4.

At the West side, all the ducts from the Converter low level hoods will merge to form a common duct, which turns vertically upwards to pass through the charging floor at the end of the charging bay. From there it is routed upwards in an inclined direction towards the West and then horizontally northwards over the existing offices before exiting the steel plant building through the North wall.

The alternative option would be to route the extraction ducts from the low level hood of the East Converter northwards out of the steel plant building adjacent to the North East door. However, this alternative route would involve a reduction in headroom for vehicular access.

To avoid increased restriction on vehicle access, the ductwork route under the charging floor shown in Figure 2 has been selected as the preferred route.

The cross sectional area of each of the low level extract ducts has been estimated to be around $1.7m^2$. Inspections at the steel plant indicate that there are few obstructions under the charging floor. However, due to obscuration of certain areas by sheeting, the structural characteristics of all of the underside of the charging floor could not be completely determined and should be confirmed when full access is available.

(b) Scan Lance Ducting:

Figures 2 and 3 show that the new ductwork from the existing fume extraction port at the North side of the roof of the Scan Lance unit will be routed up the adjacent structural column, following the route of the existing duct to above the crane rail level. The new duct will then be routed northwards across the bay above the crane and it's associated equipment towards the Converters.

At column line A/B, the duct will be routed downwards to meet the main extraction duct serving the low level hoods, as shown in Figures 3 and 4.

(c) Roof Extraction Ducting:

As shown in Figures 3 and 4, the two extraction ducts from the roof space of the lance aisle will be routed down the outside of the roof before joining at the apex of the lower roof. The common duct will then be routed down the outside of the steel plant building, to join the main low level extraction duct as it exits the steel plant.

(d) Fabric Filter Ducting:

As shown in Figures 2 and 3, the main extraction duct will pass through the North wall of the steel plant building and will be routed directly North towards the fabric filter plant. This route will require the modification of the existing pipe rack, though preliminary investigations indicate that such modifications will be minor.

5.5 DUST REMOVAL SYSTEM

The two types of dust removal equipment mainly used for secondary fume cleaning are:

- electrostatic precipitators.
- fabric filters.

The relative advantages and disadvantages of each type are briefly summarised below.

5.5.1 Electrostatic Precipitators

Electrostatic precipitators have been used in a number of steel plant secondary fume control systems and, in the case of a retro-fit project in a congested site, this type of plant has the advantage of a small plot area. Electrostatic precipitators have a lower operating cost than fabric filters due to the lower pressure drop and can operate at higher temperatures. However, electrostatic precipitators have lower cleaning efficiency than fabric filters. The cleaning efficiency of electrostatic precipitators is influenced by the characteristics of the dust and can be adversely affected by sudden changes in the volume of fume and high dust loads.

5.5.2 Fabric Filters

Fabric filters are the most commonly used method of cleaning secondary fume in the steel industry. Fabric filters have the advantage of high cleaning efficiency, are capable of removing very small particles, can handle high dust loads and collect the dust in a dry condition. This type of filter can also satisfactorily handle the wide variations in gas flow rate, small particle size and sudden changes in dust concentration experienced in secondary fume cleaning systems. Fabric filters, however, have the disadvantage that they can only be used for cleaning gases at relatively low temperatures. They involve high capital cost and, due to their relatively large pressure drop, have higher operating costs than electrostatic precipitators.

5.5.3 Other Fume Cleaning Techniques

Static cyclone separators are not regarded as suitable for secondary fume cleaning due to their low efficiency, particularly at low particle sizes. However, consideration could be given to installing this simple, low cost equipment as a pre-treatment stage of a bag-filter plant.

Wet scrubbing techniques are not regarded as appropriate for secondary fume cleaning due to their high pressure drop, overall capital cost and potential difficulties associated with handling the recovered wet sludge.

If the bag filter plant was physically closer to the low level hoods of the Converters, a "spark arrestor" would be installed upstream of the bag filter plant. However, the residence time of the fume in the length of ductwork between the Converters and the bag filter plant proposed at Dunaferr is considered to be sufficient not to require a spark arrestor.

5.5.4 Comparison of Fume Cleaning Techniques

The following table compares the cleaning efficiency and other key parameters of the various types of fume cleaning equipment:

Collector	Approximate Collection Efficiency % η			Equipment Characteristics				
	10 μm	5 μm	1 μm	High Dust Loads	Dry Product	Capital Cost	Operating Cost	Technical Complexity
Cyclone	87	73	27	Y	Y	L	M	L
Basic Scrubber	97	94	55	Y	N	L	L	L
High η Venturi Scrubber	>99.9	99.9	98.5	Y	N	H	H	M
Dry ESP	>99.5	>99.5	>99.5	Care	Y	H	L	H
Wet ESP	>99.5	>99.5	>99.5	Care	Y	H	L	H
Fabric Filter	>99.9	>99.9	>99.6	Y	Y	H	H	M

Based on the above comparisons, a fabric filter cleaning system is proposed for capturing the dust in the secondary fume collected at the Dunaferr steel plant.

The key features of the proposed fabric filter plant and its ancillary facilities are briefly described below.

5.6 KEY FEATURES OF FABRIC FILTER PLANT

The most appropriate type of fabric filter is a conventional tubular bag type filter, with pulse jet cleaning and the following key features:

Option 1.

Volume Capacity	1 200 000 Am^3/h (max.)
Gas Temperature	130°C (max.)
Suction at Inlet	600 mm/H_2O
Inlet Dust Loading	3-8 g/Nm^3
Outlet Dust Loading	< 15 mg/Nm^3

Bag Material: Polyester type needlefelt

Option 2.

Volume Capacity	760 000 Am^3/h (max.)
Gas Temperature	130°C (max.)
Suction at Inlet	350 mm/H_2O
Inlet Dust Loading	3-8 g/Nm^3
Outlet Dust Loading	< 15 mg/Nm^3

Bag Material: Polyester type needlefelt

The polyester bag filter material is widely used for the proposed application within the steel industry and is available world-wide. The disadvantage of polyester type materials is that the recommended maximum operating temperature is around 130°C. This limitation on the operating temperature requires an ambient air bleed into the secondary fume gas stream to protect the bags against over-temperature, particularly during charging of the Converter. However, this periodic additional volume of cooling air increases the size and cost of the bag filter plant and the associated running costs of the electrically driven fans. The bag filter plant can operate at a higher gas temperature if a superior bag material is used and temperatures of up to 200°C are possible with specialist fabrics, eg Nomex. Whilst this would eliminate the requirement for a cooling air bleed, the use of the more sophisticated types of bag material could significantly increase the initial capital cost of the plant and the routine replacement cost of the bags. There may also be difficulties over the availability of high temperature bag materials from within Hungary and such bags may need to be imported. However, this is subject to confirmation.

Since preliminary calculations indicate the combined capital and operating costs of the more sophisticated bag material is not significantly lower than the traditional polyester material, the latter is at present recommended.

The dust removed from the gas stream will collect in hoppers under each bag filter compartment. The dust will be removed from the hoppers by drag link conveyors or other means and delivered to a materials handling system, which will discharge the dust into a storage hopper. Dust discharged from the storage hopper through a rotary valve or other device can be transported for further processing or disposal by road vehicle. The current disposal route for the dust recovered from the primary fume collection system of the LD Converters is via the sinter plant/blast furnace, though the expected disposal route for the dust recovered from secondary fume at Dunaferr is at present uncertain. The use of a storage hopper and vehicle transport offers flexibility in the method of dust usage. The expected dust production rate has been calculated to be between 0.5 and 1.4 tonnes per hour, depending on plant operation.

The proposed location of the bag filter plant is an unoccupied plot of land at the North side of the steel plant, between the existing cable/pipe racks and a railway line.

This site has been chosen for the following reasons:

- Proximity to the LD Converter building.
- Availability of sufficient area for the filter plant and ancillary equipment.
- Close proximity to electrical services.
- Construction of the filter plant will not disrupt the operation of the steel plant.
- The site is level.

Figure 2.1 shows the proposed layout of the bag filter plant for Option 1. Because of the limited width of the plot of land available, 2 separate bag filter units are proposed. However, detailed engineering design may enable a single bag filter plant to be used.

In the case of Option 2, it is feasible to accommodate a single bag filter unit in the space available, as shown in Figure 2.2.

Photographs of the proposed location of the bag filter plant and its ancillary equipment are shown in Plates 7 and 8 of Annex 5.

5.7 EXHAUST FANS

For maximum security, three 50% capacity fans would be preferable. However, due to the high capital cost of fans, it is considered that the installation of a stand-by fan is not justified.

Hence, the proposed configuration is two exhaust fans, each capable of handling up to 50% of the maximum volume of fume extracted. In the event of outage of 1 fan, the secondary fume collection system can continue operating at reduced capacity.

The fans will be located downstream of the bag filters, which will minimise erosion and the incidence of imbalance due to uneven shedding of accumulated deposits. This arrangement also allows a discharge stack to be used.

In order to minimise the risk of extended downtime, it is essential that strategic spare components for the fan/drive units such as bearings, impeller, etc, are kept on site and that an effective preventative maintenance programme is adopted.

The performance of a fan varies according to the operating conditions. For conservative design, the fan duty and the design rating of the drive motor should be based on the minimum temperature of the collected fume, with the fan being capable of operating at the maximum temperature continuously.

The optimum efficiency of the fans should be chosen to be below the maximum design flow, since the fans are likely to operate below their maximum duty for long periods.

Due to the intermittent and variable volume of secondary fume generated within the steel plant, there is scope to reduce the running costs by matching the fan operation to the volume of fume generated. The two types of fan drive typically used for this application are:-

- fixed speed electric motor; (with fan suction damper to control flow)
- variable speed electric motor.

The advantages and disadvantages of each type of drive are summarised below:-

Fixed speed drives are:-

- lower in capital cost
- smaller in size than variable speed drives
- less complex and potentially more reliable
- more suitable for systems with steady flows.

Variable speed drives:-

- offer scope to conserve electrical energy consumed by the fan
- can respond to process changes
- automatically provide a soft start for large loads.

Preliminary investigation suggests that the payback on the additional investment for variable speed drives is likely to be between 3 and 4 years and the budget estimate shown in Section 11 includes this feature. However, it is recommended that more detailed analysis is undertaken at the detailed engineering stage, particularly when the potential additional demands on the secondary fume cleaning system from possible future ladle steelmaking equipment is clarified.

Centrifugal fans are the most commonly used type of fan in this application. With the use of a variable speed drive, the detailed mechanical design of the centrifugal fan needs careful consideration, since the frequent speed changes of a variable speed drive can make the impeller vulnerable to fatigue failure.

The alternative types of fan that could be considered for secondary fume collection are axial fans, with variable pitch blades or mixed flow radial tipped centrifugal fans.

Fixed speed, single stage axial fans can be designed to achieve variable flow through the variation of the pitch of the blades, thus minimising the risk of fatigue problems. The main disadvantages of variable pitch axial fans are susceptibility to blade erosion, risk of stalling on turn-down and high cost.

Mixed flow radial tip fans are designed to be used in rugged operations. The fan has a low inertia impeller, which is well suited to a variable speed drive. The mixed flow fan has a similar efficiency to a centrifugal fan but the capital cost is typically around 25% higher.

The most proven type of fan for the proposed bag filter application is the high efficiency aerofoil centrifugal fan and is therefore the preferred type.

The outline fan specification is as follows:

Option 1:

No. of fans: 2

Per Fan:

Inlet Volume:	600 000 Am^3/h
Inlet Temperature:	Max 130°C
Pressure rise:	1 100 mm H_2O
Power:	1 800 kW
Noise Rating:	< 85 dB(A) at 1m

Option 2:

No. of fans: 2

Per Fan:

Inlet Volume:	380 000 Am^3/h
Inlet Temperature:	Max 130°C
Pressure rise:	700 mm H_2O
Power:	1 400 kW
Noise Rating:	< 85 dB(A) at 1m

Appropriate noise attenuation measures, such as silencers and acoustic insulation, will be used to achieve acceptable noise levels.

5.7 DISCHARGE STACK

The height of the discharge stack from the bag filter plant will be subject to discussions with the environmental regulatory authorities.

A commonly accepted guideline is that the minimum stack efflux velocity should be 15 m/s for this type of application. In the case of Option 1, the secondary extraction load will vary between 175 000 Nm^3h and 800 000 Nm^3/h. Based on the above criteria, two stacks and an efflux temperature of 100°C, a minimum velocity of 15 m/s at average flow will equate to a stack diameter of around 2.9m. The corresponding velocity at the maximum flow would be approximately 24 m/s, which is acceptable due to the low dust loading.

In the case of Option 2, the secondary extraction load will vary between 43 000 Nm^3/h and 525 000 Nm^3/h. Based on the above criteria, one stack and an efflux temperature of 100°C, a minimum velocity of 15 m/s at average flow will equate to a stack diameter of around 3.1m. The corresponding velocity at the maximum flow would be approximately 28 m/s, which again is acceptable due to the low dust loadings.

Based on commonly used guidelines, the stack height should be around 6 metres higher than the nearest building. Since the nearest building will be the bag filter plant itself, the stack height will be over 28m.

It is possible that the environmental regulatory authority may seek to claim that the relevant "nearest" building is the steel plant shop. In these circumstances the stack height would need to be over 81m, which is considered unreasonably high for a stack discharge from a bag filter plant.

5.9 FUTURE OPERATIONS

Dunaferr Steelworks have requested that sufficient capacity be designed into the secondary fume cleaning system to accommodate the additional fume from possible future secondary metallurgical treatment stations, such as a ladle furnace. The nature of the secondary fume generation at the basic oxygen converters is intermittent, with the peak fume load occurring for roughly 2 minutes in every 40 minutes of the converter production cycle. This cyclic pattern of secondary fume generation will permit the intermittent fume from additional future metallurgical treatment facilities to be accommodated by the secondary fume cleaning system without increasing it's capacity.

In the case of both Option 1 and Option 2, there is sufficient capacity in the secondary fume cleaning system so that, with reasonable operational scheduling, additional supplementary loads of well over 200 000 Am^3/h could be accommodated for approximately 30 minutes over a 40 minute period. This should be sufficient to accommodate the fume from additional metallurgical treatment facilities, such as a ladle furnace, that may be installed by Dunaferr at some future stage.

SECTION 6

OPERATING CONTROL AND INSTRUMENTATION

SECTION 6

OPERATING CONTROL AND INSTRUMENTATION

6.1 PHILOSOPHY

The effectiveness and energy efficiency of the proposed secondary fume cleaning system at the Dunaferr steel plant will be enhanced by the control and instrumentation system. The principal functions of the system will be to achieve safe and effective extraction of secondary fume, while reducing consumption of electrical power.

Due to the intermittent and variable nature of secondary fume generated during steel making operations, the optimum selection of flow rates at key extraction points cannot be achieved by means of pre-determined sequences. The control philosophy of the secondary fume collection system to minimise energy consumption is therefore based on signals from steel making operations and measurement of ambient fume in the roof above the Converters.

To minimise power consumption, the main extraction pressure is held constant, but the flow reduced, except where required at selected extraction points. This entails the use of dampers at each extraction point and mechanisms for optimising the damper settings.

The control of dampers and fans will be automatic. Whilst automation increases the capital cost of the plant, these costs are recovered by savings in energy consumption. The system design should be such that in the event of a failure, operation will revert to conventional operation at the maximum design extraction rate.

The system will be supervised via a terminal in an existing steel plant control room. In the event of a failure of the terminal, the system will be designed to continue in operation under PLC control. Local control panels will be provided for maintenance, test and commissioning purposes.

The typical extraction volumes expected to be necessary to control the secondary fume in the case of Options 1 and 2 are shown in Annex 3. Whilst these figures are based on idealised steel making operations, the graphs in Annex 3 show that the step changes offer the opportunity to match the fan settings to the large variations in fume emissions, thus saving energy.

6.2 CONTROL REQUIREMENTS

6.2.1 Equipment and Installation

Control and instrumentation (C&I) equipment will be standardised with the equipment currently installed at the Dunaferr Steelworks. PLCs will be "Omron" models, compatible with existing systems at the plant. Instruments will be Rosemount, Siemens or equivalent loop-powered, 24 Vdc, 2-wire devices with 4-20 mA outputs. Control and instrumentation (C&I) equipment should be installed to BS6739 or equivalent professional standard.

All the ancillary equipment required for commissioning, adjustment and maintenance of the C&I items will be included in the scope of supply.

The notional concept of the control scheme devised for cost estimation purposes is shown in Figure 6.

6.2.2 Interfaces

Comprehensive, straightforward operator interface facilities will be provided for monitoring and controlling the operation of the secondary fume cleaning system. The new systems will interface with the existing control systems within the steel plant via discrete (individually-wired) signals; it is provisionally assumed that there will be around 32 digital inputs and outputs, and 8 analogue signals between the secondary fume cleaning control system and the existing systems.

6.2.3 Dampers

Each branch of the extraction system will be fitted with a modulating damper designed to fail open and be padlockable in the closed position for maintenance purposes. The fans will be fitted with individual dampers to permit isolation for maintenance purposes. The design and location of dampers will be such as not to impair the operation of the fan. All dampers and electrical isolators will be lockable to allow safe maintenance. The tentative location of the control dampers is shown in Figure 1 of Annex 4.

6.2.4 Fan Speed and Pressure Control

The suction pressure in the main extract duct will be measured and the pressure maintained constant by automatic adjustment of the fan speed.

The fan speed should be changed in discrete steps rather than be continuously modulated. The specific speeds should be determined during commissioning to avoid mechanical resonance, thereby prolonging the life of the equipment and reducing acoustic noise.

6.2.5 Extraction Hood Flow Control

During the phases of the production cycle when secondary fume emissions are low, the flow rate through particular extraction points will be reduced to save energy. This will be implemented by control dampers in the extraction ducts, which will be partially closed when the appropriate interface signals are received from the steel production control system.

6.2.6 Roof Extraction Flow Control

The extraction from the lance hood aisle roof will be controlled by "long-path" obscuration particulate monitors located in the roof, which will adjust the dampers to reduce the extraction rate when fume is not present.

6.2.7 Temperature Control

Temperature will be measured upstream of the bag filters and in the event of the temperature increasing towards 130 °C, the damper in the lance aisle roof and air bleed ducts will be opened progressively to maintain the temperature at or below 130°C.

6.2.8 Bag Cleaning

A separate PLC-based control system will be supplied for each of the two bag filter groups. Cleaning will be automatic, initiated on a timed cycle, with the bag modules selected in sequence. Dampers will isolate the entry and exit of the module while cleaning is taking place. Manual override of selected filters will be possible, for convenient maintenance and testing.

6.2.9 Bag Blinding Detection

A differential pressure transmitter will be installed across each bag filter group. The measurements will be continuously recorded and high level alarms provided.

To detect a blocked filter, the recording may be examined and correlated with the automatic cleaning sequence. Normal filter units, when switched back into service after cleaning will produce a measurable decrease in differential pressure across the group. A "blind" filter, however, will produce little or no change.

6.2.10 Burst Bag Detection

Individual filter units with faulty bags may be identified by observing the recording of the particulate monitor. When a filter with faulty bags is switched out of service for cleaning, the particulate signal will decrease significantly.

SECTION 7

EMISSION MONITORING

SECTION 7

EMISSION MONITORING

Regular or continuous emission monitoring is necessary for two main reasons:

a) It will enable the performance of the secondary fume cleaning system to be monitored and will highlight any operational abnormalities.

b) The results can be used to demonstrate Dunaferr's compliance with environmental legislation or any specific agreements reached with the regulatory authorities.

It is assumed that any arrangements for emission monitoring will comply with the current standards applicable in the European Union. In the case of the United Kingdom, current standards state that where bag filters are used, the efficiency and incidence of malfunction should be indicatively monitored by means of a pressure drop sensor and continuous particulate monitoring of the discharged gases.

Particulate emissions in the form of dust can be continuously monitored by instruments that project infra-red or visible light across a stack. Visible rather than infra-red light is appropriate where the particle size distribution extends significantly below 500 nm.

In order to minimise the risk of fouling of the instrument by the clean exhaust gas, it is necessary to provide a purge using clean instrument air or, if available on site, dry nitrogen.

Other potential types of continuous monitor are particle impingement or "triboelectric" detectors, which measure particulate emissions by detecting the charge transferred from an electrode to the particles impinging on it. This type of instrument is highly sensitive, with a claimed accuracy of 0.1mg/Nm^3.

At present in the UK, the type of continuous monitoring technique to be used is not prescribed by the Environmental Regulatory Authority and the technique adopted is at the discretion of the operating company. However, the continuous particulate monitoring technique most widely used within the UK steel industry and the one generally considered to represent the current best practice is the optical instrument.

The concentration measurements of particulate emissions using optical instruments are significantly influenced by the physical characteristics of the particulate and can be affected by the temperature and pressure of the gas stream. In-situ calibration by means of isokinetic sampling will be required; typically twice a year.

Apart from monitoring particulate emissions, it would also be desirable to measure the flow (or suction pressures) at the main branches of the extraction ductwork, in order to monitor the satisfactory operation of the fume cleaning system and assist the achievement of the optimum balance of the system.

All key measurements should be continuously recorded and any abnormalities outside the acceptable limits should produce visual and audible alarms.

SECTION 8

ASSESSMENT OF ENVIRONMENTAL IMPROVEMENT

SECTION 8

ASSESSMENT OF ENVIRONMENTAL IMPROVEMENT

The proposed secondary fume control system for the Dunaferr steel plant will greatly reduce the present level of particulate emissions to the atmosphere as discussed below.

8.1 STACK EMISSIONS

Typical bag filter plants normally achieve particulate emission levels below 10 mg/Nm³. However, to cover all operational conditions, suppliers usually guarantee bag filter performance to < 15 mg/Nm³, as the peak emission at any time during normal operation.

The anticipated future Hungarian limit for secondary fume emissions from steel plant operations is likely to be < 50 mg/Nm³; [compared to the current UK standard for secondary fume emissions from steel plants of < 30 mg/Nm³ and the equivalent German standard of < 20 mg/Nm³].

Based on a guaranteed filter performance of 15 mg/Nm³ and the sealed roof concept described in Section 5, it is anticipated that the particulate emission from the stack of the secondary fume cleaning plant would be typically between 1 to 2 kg/h, with a peak emission rate of 3 to 4 kg/h. This compares with the present regulatory limit of 30 kg/h for the primary gas cleaning stack of the LD Converters.

8.2 WORKPLACE EMISSIONS

It is expected that the atmospheric dust concentration in the vicinity of the operating floor during charging operations will be < 7 mg/Nm³. However, based on operational experience, equipment suppliers will usually only guarantee performance to < 15 mg/Nm³ as a peak work place emission at any time during normal operating conditions. The zone for sampling will usually be defined as the area bounded by the charging floor at an elevation of 1.5m from the charging floor.

The lower rate of fume extraction from the roof space in Option 2 compared to Option 1 may lead to slightly higher drop-out of particulate from the fume accumulating in the roof space. However, it is not possible to quantify the extent of this phenomenon.

During other operations, the expected level of atmospheric dust, measured at the same position should be less than $2mg/Nm^3$. The current UK regulations regarding workplace atmospheric dust levels state occupational exposure standards of $10\ mg/Nm^3$ 8-hour Time Waited Average (TWA) total inhalable dust and $5mg/m^3$ TWA total respirable dust.

The installation of a secondary fume control system at the Dunaferr steel plant should minimise releases to atmosphere, reduce the current secondary emissions by over 95% and prevent visible releases to atmosphere. The environmental standards expected to be achieved by the installation of the proposed plant will meet the current and likely future requirements of the environmental legislation of both Hungary and the European Community.

SECTION 9

SUMMARY OF MAIN PLANT ITEMS

SECTION 9

SUMMARY OF MAIN PLANT ITEMS

ITEM NO.	DESCRIPTION	OPTIONS 1 (& 2) NO. OFF
1.0	**EXTRACTION HOODS**	
1.1	LD Converter Low Level Hoods	2 Off
2.0	**DUCTWORK - LOW LEVEL EXTRACTION**	
2.1	Ductwork from LD Converter Low Level Hoods	1 Set
2.2	Ductwork from Scan Lance	1 Set
3.0	**DUCTWORK - HIGH LEVEL EXTRACTION**	
3.1	Ductwork from Lance Aisle Roof Monitor	1 Set
4.0	**DUCTWORK - COMMON**	
4.1	Ductwork - To Bag Filter	1 Set
4.2	Ductwork - Air Bleed	1 Set
5.0	**CONTROL DAMPERS**	
5.1	Low Level Hood Dampers	4 Off
5.2	Roof Extract Dampers	2 Off
5.3	Scan Lance Damper	1 Off
5.3	Air Bleed Damper	1 Off
6.0	**EXPANSION JOINTS**	
6.1	Expansion Joints	1 Set
7.0	**FUME COLLECTION**	
7.1	Bag Filter Plant	2 Sets (1 Set)
7.2	Interconnecting Ductwork & Isolating Dampers	1 Set
7.3	ID Fans, Drive Motors & Associated Controls	2 Sets
7.4	Stack	2 Off (1 Off)
7.5	Dust Handling Equipment	2 Sets (1 Set)
7.6	Dust Storage Equipment	1 Set
7.7	Dust Emission Monitoring Equipment	2 Sets (1 Set)

8.0	**STRUCTURES**	
8.1	Low Level Ductwork Support and Access	1 Set
8.2	High Level Ductwork Support and Access	1 Set
8.3	Common Ductwork Support and Access	1 Set
8.4	Roof Closure Steelwork/Sheeting	1 Set
8.5	LD Converter Enclosure Improvements	2 Sets
8.6	Damper Steelwork	1 Set
8.7	Steelwork for Bag Filter, Fans, Stack and Access	2 Sets (1 Set)
9.0	**ELECTRICS**	
9.1	LV Motor Control Equipment	1 Set
9.2	HV Motor Control Equipment	1 Set
9.3	Local Control Station	1 Set
9.4	Process Control System	1 Set
9.5	Field Instrumentation	1 Set
9.6	Cabling and Earthing	1 Set
9.7	Transformers	1 Set
9.8	Local Isolators	1 Set
9.9	Field Alarms	1 Set
9.10	Fire Alarm and Protection Systems	1 Set
9.11	Instrumentation	1 Set
10.0	**SERVICES**	
10.1	Compressed Air Pipework	1 Set
11.0	**CIVILS**	
11.1	Foundations and Piling	
11.2	MCC Building and Services	
11.3	Foundation Plates and Anchorages	

SECTION 10

SUMMARY OF MAJOR WORK

SECTION 10

SUMMARY OF MAJOR WORK

10.1 MAJOR CIVIL AND STRUCTURAL WORK

10.1.1 Civil Works

Geophysical and topological survey of the site

Site clearance

Diversion of existing aboveground services

Diversion of existing underground services

Excavations

Foundations

Foundation anchorages

Drainage works

Hardstanding and roads

Electrical Substation

Hard standing for cranes

Installation of concrete plinths

10.1.2 Structural Steel Work

Support steel and access platforms for ductwork

Support steel for low level hoods

Support steel and structures for fabric filter

10.2 SUMMARY OF MAJOR ERECTION WORK

10.2.1 Low Level Hoods

Installation of low level extraction hoods and supports

10.2.2 Duct Work

Installation of outlet ducts from low level hoods

Removal of existing Scan lance duct work

Installation of new Scan lance duct work

Installation of air bleed duct work

Installation of expansion joints

Installation of dampers and associated controls

Installation of insulation

10.2.3 Roof Extraction

Installation of roof sheeting

Installation of roof extraction duct work

Installation of dampers and associated controls

10.2.4 Fabric Filter Plant

Installation of duct work

Installation of fabric filter

Installation of fans

Installation of motors

Installation of stack(s)

10.2.5 Electrics, Controls and Mechanical Services

Installation of all electrical services, controls, instrumentation, compressed air services and ancillary facilities.

SECTION 11

FINANCIAL EVALUATION

SECTION 11

FINANCIAL EVALUATION

11.1 Capital Cost Estimate

The table overleaf outlines the main capital cost items. Prices have been obtained from a combination of supplier budget quotations and "in house" calculations.

Due to the difficulty in obtaining prices for Hungarian manufacture, all prices are based on a UK location. To account for the differences between Hungary and the UK, a factor of 0.65 has been used to adjust the prices of locally sourced items. This factor has been based on information received from trade journals and the Department of Trade and Industry.

TABLE 11.1

Comparison of Capital Cost Estimates of Option 1 and 2

Description	Estimated Cost - US Dollars		Source
	Option 1	Option 2	
1. Capital Equipment			
Hoods	38 500	38 500	Supplier Budget Prices
Enclosure modifications	75 000	75 000	Supplier Budget Prices
Ductwork	443 000	385 000	Supplier Budget Prices
Dampers	193 000	193 000	Supplier Budget Prices
Expansion Joints	54 000	54 000	Supplier Budget Prices
Bag Filter Plant	3 536 000	1 872 000	Supplier Budget Prices
ID Fans	624 000	416 000	Supplier Budget Prices
Monitoring Equipment	38 500	19 500	Supplier Budget Prices
2. Structures			
Ductwork Support	94 000	94 000	Supplier Budget Prices
Roof Sealing	73 000	73 000	Supplier Budget Prices
Enclosure Sealing	26 500	26 500	Supplier Budget Prices
3. Civils			
Foundations & Piling	530 000	345 500	In House Information
Buildings & Services	53 000	35 000	In House Information
Plates & Anchorages	53 000	35 000	In House Information
Civil Design	65 000	43 000	In House Information
4. Electrics			
Transformers & Cabling	412 000	355 000	Supplier Budget Prices
Process Control	51 000	48 000	Supplier Budget Prices
Field Instrumentation	22 000	21 000	Supplier Budget Prices
5. Services			
Compressed Air	58 500	50 000	In House Information
Sub Total	**6 440 000**	**4 179 000**	
6. Project Management & Engineering	296 000	192 000	In House Information
7. Contingency (15%)	1 010 000	656 000	In House Information
TOTAL	**7 746 000**	**5 027 000**	

Note: 1 US Dollar = 0.635 UK£ = 175 Hungarian Forints

11.2 Operating Cost Evaluation

TABLE 11.2

Operating Cost Estimate

Description	**Annual Electric Running Costs**		**Annual Maintenance Costs**	
	Option 1 US Dollars	**Option 2 US Dollars**	**Option 1 US Dollars**	**Option 2 US Dollars**
1. Capital Equipment				
Hoods & enclosures	-	-	3 500	3 500
Ducts	-	-	7 000	7 000
Dampers	-	-	3 000	3 000
Expansion joints	-	-	1 000	1 000
Fume arrestment & fans	510 000	376 000	105 000	75 000
Sub Total	**510 000**	**376 000**	**119 500**	**89 500**
2. Electrical Services	31 000	25 000	4 000	4 000
3. Other Services	112 000	92 000	500	500
TOTAL	**653 000**	**493 000**	**124 000**	**94 000**

OVERALL OPERATING COSTS

Option 1 - Estimated Total Annual Operating Cost = US$ 787 00

Maximum annual steel output with 2 LD Converter Operation = 1 000 000 tonnes

∴ Cost of operating secondary pollution control = US$ 0.787/tonne

Option 2 - Estimated Total Annual Operating Cost = US$ 587 000

Maximum annual steel output with 1 LD Converter Operation = 600 000 tonnes/annum

∴ cost of operating secondary pollution control = US$ 0.9978/tonne

Note: Option 1 output is a hypothetical future production level which exceeds current expectations.

SECTION 12

PROGRAMME

Drawing No	Drawn	Date	DO Chk	Date	Eng Chk	Date	App	Date	Revision
141325/14	jat	8.5.96							

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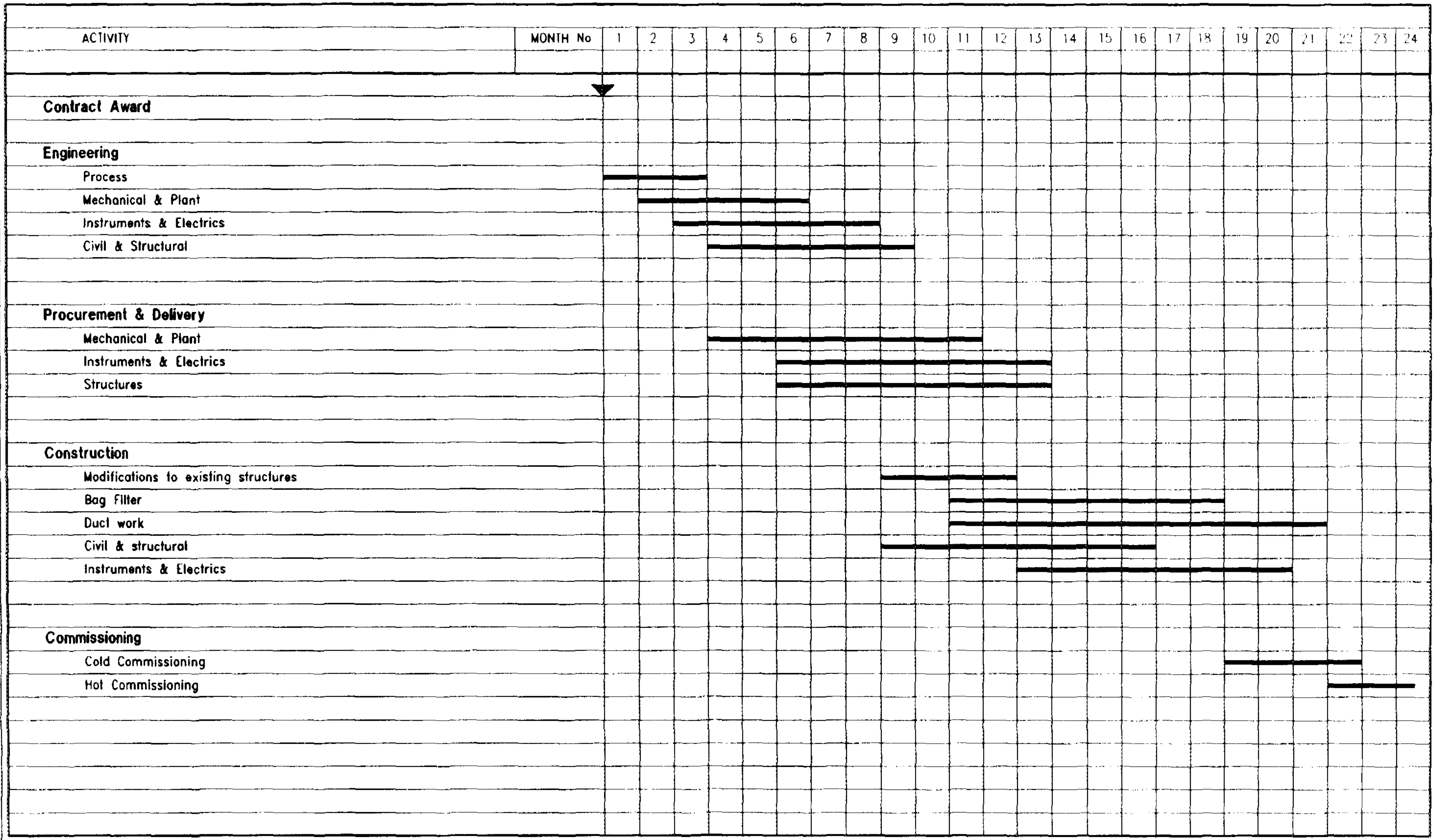
Consulting Engineers Sheer House West Byfleet Surrey KT16 6NL
Tel 0932 343271 Fax 0932 348037

A3 CAD 2 DATE 08/05/1996 TIME 1525



McLellan

UNIDO
Project No TF/HUN/94/E90
Dunaferr Steelworks – Hungary

Indicative Programme

Drawing
141325/14

ANNEXES

ANNEX 1

HOT METAL MIXER AND SLAG RABBLING STATION FUME ABATEMENT

ANNEX 1

HOT METAL MIXER AND SLAG RABBLING STATION FUME ABATEMENT

Detailed study of the existing fume extraction system of the Hot Metal Mixer and Slag Rabbling Station is outside the scope of the McLellan Contract with UNIDO. However, the present system is not operating satisfactorily and, therefore, suggested improvements to the existing arrangement are described below.

The existing fume extraction system consists of three hoods positioned to:

- collect fume during hot metal transfer from the ladle into the Mixer.
- collect fume during pouring from the Mixer into the charging ladle.
- collect fume from the slag rabbling operation.

The above system is not capturing the fume satisfactorily, resulting in excessive fume emissions within the building and escape of fume to the atmosphere from the roof of the building.

Integration of fume collection from the hot metal Mixer and Slag Rabbling Station into the proposed new secondary fume abatement system is not recommended for the following reasons:

- the high cost of ductwork to integrate the two systems
- the difficult and convoluted ductwork route that would be required to link the systems
- the incorporation of such additional intermittent fume loads in the new fume cleaning system of the Converters could limit the ability to accommodate additional fume loads from future metallurgical equipment such as a ladle furnace, unless additional fume cleaning capacity is installed

- it should be feasible to improve the effectiveness of the existing fume collection system of the Mixer and Rabbling Station at modest cost.

In order to improve the effectiveness of the existing fume collection system of the Mixer and Slag Rabbling Station, the following actions are recommended:

1. Modify the present charging door of the Mixer to prevent the door deflecting fume away from the canopy hood extraction system. By allowing the door to move further than 90° from the horizontal, the flow of fume into the hood would be less disrupted. It is recommended that the present chain system is modified to allow the door to move to an angle of 120°, which would help channel the fume into the hood. To facilitate closing of the door, it is recommended that a pneumatic actuator, spring or other suitable mechanism is attached to the Mixer behind the door.

2. The existing fume extraction system of the hot metal Mixer and Slag Rabbling Station has a trifurcated duct to collect the fume from the three sources. A three way valve exists to control the relative extraction volumes flowing in each leg of the ducting. It is recommended that this valve is adjusted to match the prevailing operating conditions, in order to maximise the extraction flow at the principal fume source and minimise the extraction flow in the other two ducts. If this improves the effectiveness of the fume extraction, a damper system should be installed to automatically optimise the extraction flows.

3. McLellan was not able to inspect the internal condition of the ducts during the site visit, though it seems likely that a significant amount of dust has been deposited within the ducts since the plant was commissioned. It is therefore recommended that the ducts are inspected and any build up of dust removed.

4. The present extraction fan has a relatively flat performance curve. Consequently, small increases in the pressure drop within the system result in significant deterioration in the volume of flow. By modifying the existing impeller or replacing the complete fan with a unit having a more suitable characteristic, it may be possible to achieve more satisfactory performance of the fume extraction system.

5. The plume of fume generated during hot metal pouring from the Mixer into the ladle is disrupted by the profile of the Mixer. If the extraction rates are at satisfactory levels but, due to disruption of the flow, the fume is still not captured by the collection hood, it may be possible to channel the fume towards the hood by means of chain curtains. Such chains can be installed at relatively low cost and can sometimes offer a simple solution which does not interfere wit the operation of the plant.

It may be possible to solve the present fume collection difficulties at the hot metal Mixer and Rabbling Station by a combination of the above actions, together with "in house" plant development work. This would be a more cost effective and practical approach to controlling the secondary fume emissions from these sources than expanding the proposed secondary fume control system of the LD Converters to treat the fume from the Mixer and Rabbling Station.

ANNEX 2

BASIC DESIGN DATA

ANNEX 2

BASIC DESIGN DATA

A site survey of the steel plant at the Dunaferr Steelworks was carried out by McLellan in February 1996. During this period the following information was collected:

- Layout of steel plant and surrounding area
- Design criteria of existing fume abatement systems
- Current regulatory limits for atmospheric emissions
- Levels of secondary fume emission
- Temperature of secondary emissions
- Profiles and velocities of plumes of secondary fume emissions
- Present operating practices within the steel plant
- Production operating schedules of Converter vessels
- Charge weights of LD Converters and Mixer
- Rate of charging of LD Converters and Mixer
- Typical chemical analyses of LD Converter dust
- Present disposal routes of LD Converter dust
- Electrical power supply information

The following is a brief synopsis of the main information gathered during the site visit, which was subsequently used in the Design Study of Pollution Control within the steel plant.

A2.1 DESIGN OF EXISTING FUME ABATEMENT SYSTEMS

During the visit to Dunaferr, the following existing fume abatement systems were inspected:

- LD Converter Primary Fume Cleaning System
- Scan Lance Fume Extraction System
- Mixer Fume Extraction Systems (In-pouring and Out-pouring)

Rabbling Station Fume Extraction System

Bag filter Plant for Mixer and Rabbling Station Fume

Information was obtained from Dunaferr Steelworks on the design of the above systems.

Information was also gathered on the present deficiencies of the existing fume abatement equipment, the operational difficulties within the Converter Shop and the plans for future development within the steel plant.

A2.2 CURRENT REGULATORY LIMITS FOR ATMOSPHERIC EMISSIONS

The current regulatory limits for the emissions from the exhaust stack of the primary fume cleaning systems of the LD Converters and the actual emissions are summarised below:

	Regulatory Limit	**Actual Emission**
SO_2	180 kg/h	21 kg/h
CO	1500 kg/h	143 kg/h
NO_x	45 kg/h	3 kg/k
Dust	30 kg/h	24 kg/h

The environmental laws in Hungary are currently undergoing reform and Dunaferr Steelworks believe that the revised limits, which will be applicable from 1997, are likely to be as follows:-

(a) Exhaust stack of primary fume cleaning system:-

SO_2	300 mg/Nm^3
CO	650 mg/Nm^3
NO_x	400 mg/Nm^3
Dust	50 mg/Nm^3

(b) Discharge of secondary fume cleaning system:-

Dunaferr Steelworks predict that the regulatory emission limits for any secondary fume abatement equipment are likely to be:

SO_2 & NO_x	500	mg/Nm^3
Dust	50	mg/Nm^3

A2.3 SECONDARY FUME EMISSION PROFILES

During the visit to Dunaferr, McLellan carried out extensive photography and video recording of the plumes of secondary fume arising at LD Converters, Mixer and Scan Lance. Using this photographic record, the velocities, volumes and flow patterns of the secondary fume from each source were assessed. This information was used as the basis of the Design Study and sizing of the local secondary fume extraction hoods for the LD Converters.

A further subject of investigation was the extent of disruption to the naturally buoyant patterns of fume flow caused by general air movements and cross draughts within the steel plant building. The various photographs and video recordings showed that, at the time of the visit, the secondary fume flows were not significantly disrupted by draughts or normal ventilation within the building.

A2.4 SECONDARY EMISSION LEVELS

Using the data collected on the peak fume velocities, the cross sectional area of fume generation, combined with data from similar projects and other "in house" information, McLellan assessed the volumes of secondary fume generated within the steel plant at the various stages of the production cycle.

A2.5 SECONDARY EMISSION TEMPERATURES

Test work was carried out by Dunaferr Steelworks to establish the peak temperatures of the fume during the normal operation of the LD Converters. A series of measurements were taken and the following tabulation shows the "maximum" and "average" peak temperature readings at the underside of a beam, approximately 4 metres above the Converter mouth when the vessel is in the charging position.

Operation	Peak Temperature °C	
	Maximum	Average
Scrap Charging	258	216
Hot Metal Charging	954	636
Blowing	191	176
Tapping	156	128
De-slagging	63	56

A2.6 CHARGING RATES

The charging and discharging rates and other operations at the process units were timed by McLellan. The typical times for the various operations are shown below:

Process Unit	Operation *	Time (Minutes)
LD Converters	Scrap Charging	2
	Hot Metal Charging	2
	Blowing	20
	Tapping	7
	De-slagging	4
	Turn-around	5
Mixer	In-Pouring	2
	Out-Pouring	7
Scan Lance	Blowing	10

*NOTE: Intervals between operations and delays for metal analysis are not shown.

A2.7 CHARGE WEIGHTS OF LD CONVERTERS

The typical charge weights of scrap and hot metal to the Converters are:

Scrap	35 Tonnes
Hot Metal	115 Tonnes

In addition, fluxes and metallurgical additions are added to the Converters.

A2.8 CHEMICAL ANALYSES OF LD CONVERTER DUST

The following tabulations of data received from Dunaferr Steelworks illustrate the size analysis and chemical composition of the LD Converter dust captured by the primary fume cleaning system.

Table 1

Size Analysis - LD Converter Primary Dust

Size μm	Mass Under %
16.7	100.0
13.8	99.0
10.1	95.1
7.8	81.8
6.2	63.3
4.0	45.1
3.8	28.7
3.0	14.6
2.4	7.0
1.0	4.6

Table 2

Typical Chemical Analysis - LD Converter Primary Dust

Compound	Typical Analysis %
Total Fe	66.25
Fe (as Fe)	2.75
FeO	24.13
Fe_2O_3	65.15
CaO	3.72
MgO	0.18
MnO	1.28
Al_2O_3	0.30
SiO_2	1.78
Pb	0.07
Zn	0.32
Na_2O	0.04
K_2O	0.104
C	0.16
S	0.02

A2.9 PRESENT LD CONVERTER DUST DISPOSAL ROUTES

Dunaferr Steelworks reported that the LD Converter dust captured by the primary fume cleaning system is utilised by recycling it to the steel production process via the sinter plant.

ANNEX 3

EXTRACTION VOLUMES

McLellan and Partners Ltd **Calculation/Design Sheet**

☑ Sheer House, Station Approach, West Byfleet, Surrey KT14 6NL Tel 01932 343271 Fax 01932 348037

☐ Belassis Business Centre, Belasis Hall Technology Park, Billingham TS23 4AE Tel 01642 345640

☐ Innovation Centre, Mid Glamorgan Science Park, Bridgend CF31 3NA Tel 01656 667693 Fax 01656 649295

Option 1 "2/2" Operation - Calculation of Maximum Total Fume Extraction

Fume Volume

	Time	Volume		Temp	Dust
	(min)	(Am3/h)	(Nm3/h)	(oC)	(g/Nm3)
Converter					
Scrap Charging	2	195730	153547	75	0.11
Hot Metal Charging	2	372446	194413	250	7.21
Blowing	20	204635	132069	150	6.82
Tapping	7	198359	137791	120	8.14
De-Slagging	4	108574	85174	75	2.00
Turnround	5	50000	42260	50	0.05
Scan Lance					
Blowing	10	31460	16422	250	5.77
Roof Extract	2	354672	259586	100	1.92
Air Bleed (max)		209519	191942	25	0.00

Sources: 001-0001, 001-0002, 001-0006

Maximum fume when the following operations occur simultaneously:

Converter 1	Charging	372446 Am3/h	194413 Nm3/h
Converter 2	Blowing	204635 Am3/h	132069 Nm3/h
Scan Lance	Blowing	31460 Am3/h	16422 Nm3/h
Roof		354672 Am3/h	259586 Nm3/h
Bleed		209519 Am3/h	191942 Nm3/h
Maximum Total Fume		1172733 Am3/h	794432 Nm3/h
Minimum Total Fume		254635 Am3/h	174329 Nm3/h

Min. Temp.	75 oC
Max. Temp.	163 oC (Limited to 130 oC by Air Bleed)
Max Temp with Air Bleed	130 oC

Peak Dust Loadings

Converter 1	8.14 g/Nm3
Converter 2	8.14 g/Nm3
Scan Lance	5.77 g/Nm3
Roof Extraction	1.92 g/Nm3
Combined Total	7.17 g/Nm3

Fume Extraction, Fume Temperatures and Dust Loadings are shown in graphs overleaf.

Calc. No: 141325/001-0004	***All Normal Figures relate to 273K***		
Client UNIDO	Prepared P.Puntan	Date 18.3.97	
Project	Checked [signature]	Job No 141325	
Description Option 1 - "2/2" Operation - Calculation of Maximum Fume Extraction		Sheet No 1	

McLellan and Partners Ltd	Calculation/Design Sheet

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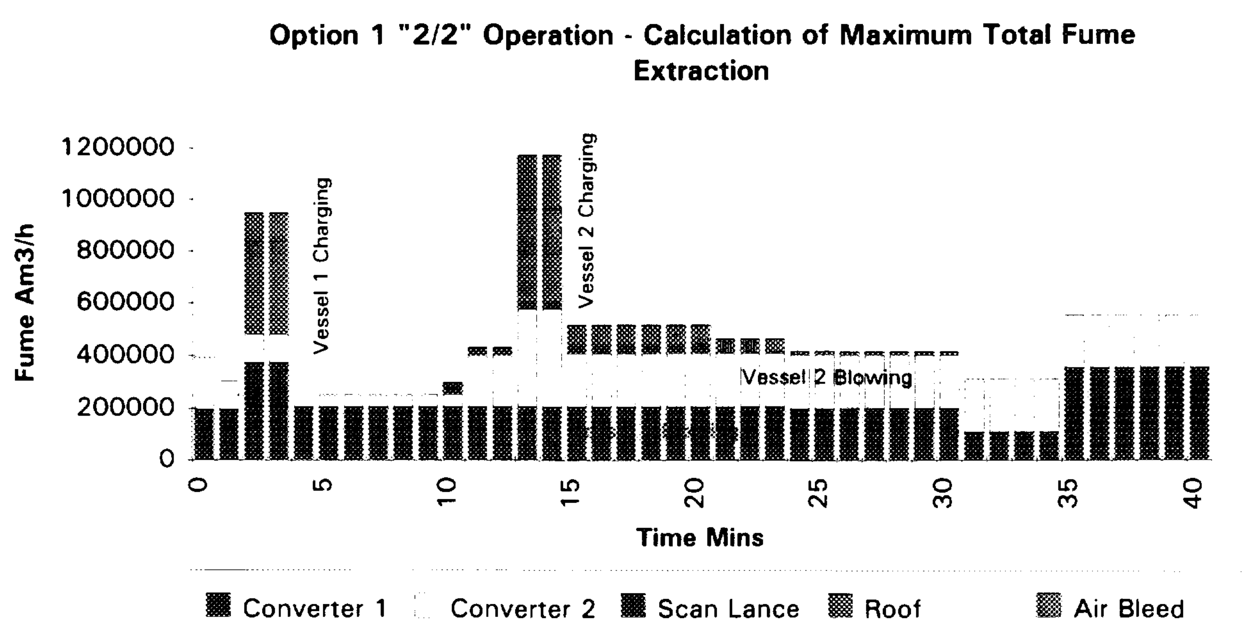
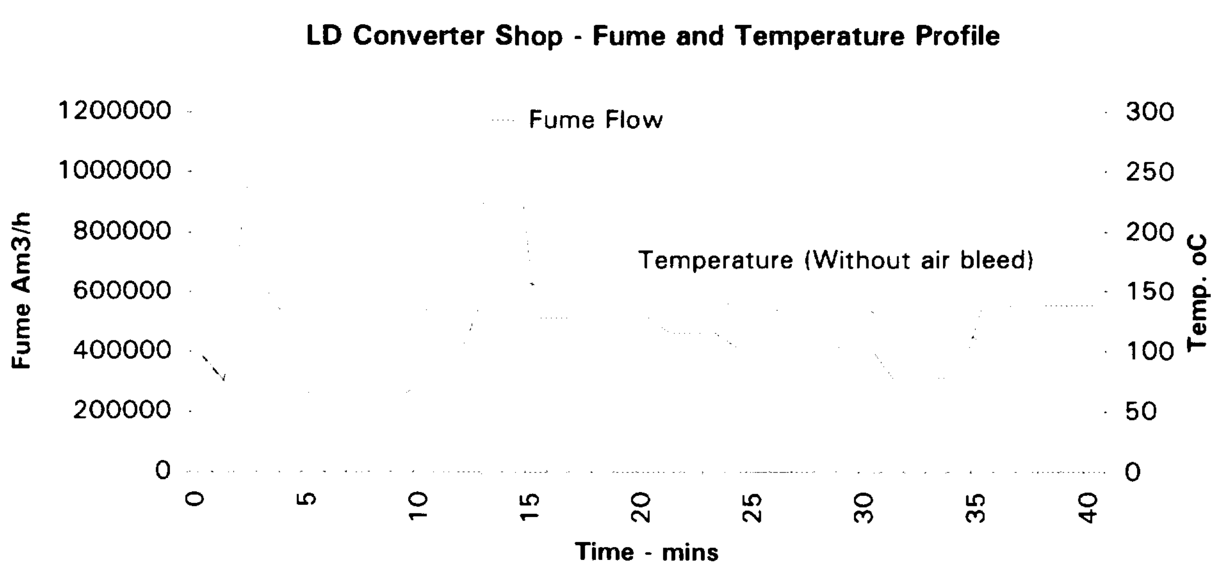
☐ Belassis Business Centre, Belasis Hall Technology Park, Billingham TS23 4AE Tel 01642 345640
☐ Innovation Centre, Mid Glamorgan Science Park, Bridgend CF31 3NA Tel 01656 667693 Fax 01656 649295

Option 1 "2/2" Operation - Calculation of Maximum Total Fume Extraction

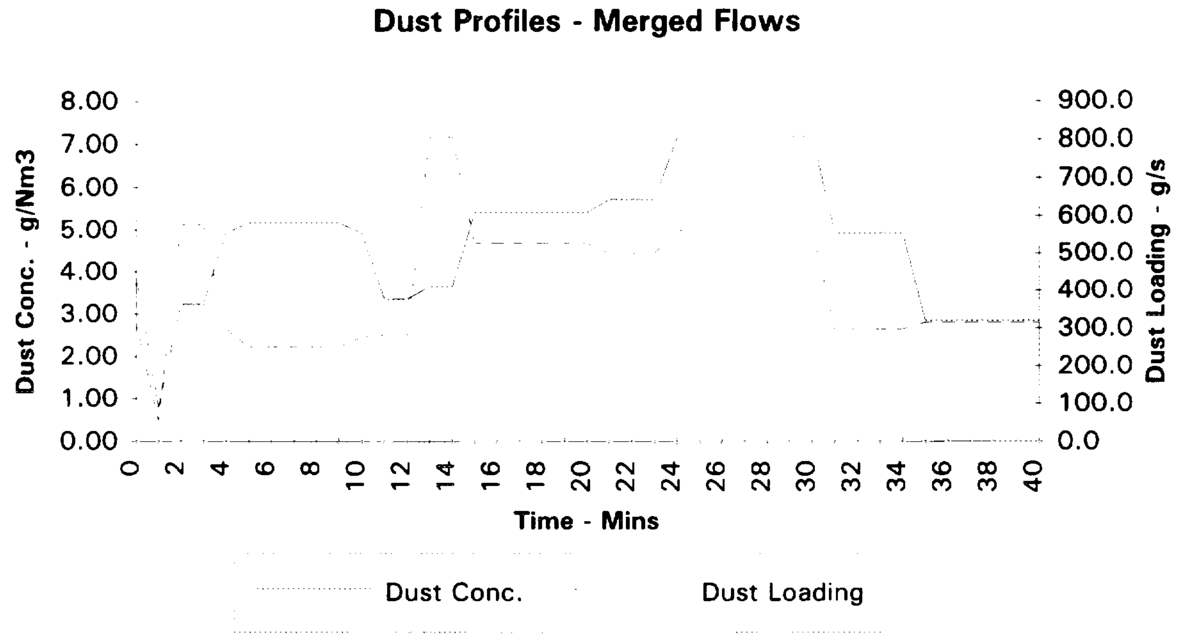




Calculation No: 141325/001-0004	*All Normal Figures relate to 273K*	
Client UNIDO	Prepared P.Puntan	Date 18.3.97
Project	Checked	Job No 141325
Description Option 1 - "2/2" Operation - Calculation of Maximum Fume Extraction		Sheet No 2

McLellan and Partners Ltd	Calculation/Design Sheet

☑ Sheer House, Station Approach, West Byfleet, Surrey KT14 6NL Tel 01932 343271 Fax 01932 348037
☐ Belassis Business Centre, Belasis Hall Technology Park, Billingham TS23 4AE Tel 01642 345640
☐ Innovation Centre, Mid Glamorgan Science Park, Bridgend CF31 3NA Tel 01656 667693 Fax 01656 649295



Calculation No: 141325/001-0004	***All Normal Figures relate to 273K***		
Client UNIDO	Prepared P.Puntan	Date 18.3.97	
Project	Checked	Job No 141325	
Description Option 1 - "2/2" Operation - Calculation of Maximum Fume Extraction		Sheet No 3	

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Option 2 "2/1" Operation - Calculation of Maximum Total Fume Generation

Fume Volume

	Time	Volume		Temp	Dust
	(min)	(am3/h)	(Nm3/h)	(oC)	(g/Nm3)
Converter					
Scrap Charging	2	195730	153547	75	0.11
Hot Metal Charging	2	372446	194413	250	7.21
Blowing	20	204635	132069	150	6.82
Tapping	7	198359	137791	120	8.14
De-Slagging	4	108574	85174	75	2.00
Turnround	5	50000	42260	50	0.05
Scan Lance					
Blowing	10	31460	16422	250	5.77
Roof Extract	4	177336	129793	100	1.92
Air Bleed (max)		202053	185102	25	0.00

Maximum fume when the following operations occur simultaneously:

Converter 1	Charging	372446 Am3/h	194413 Nm3/h
Scan Lance	Blowing	31460 Am3/h	16422 Nm3/h
Roof		177336 Am3/h	129793 Nm3/h
Bleed		202053 Am3/h	185102 Nm3/h

Maximum Total Fume	751836 Am3/h	525730 Nm3/h
Minimum Total Fume	50000 Am3/h	42260 Nm3/h

Min. Temp.	50 oC
Max. Temp.	190 oC
Max Temp with Air Bleed	130 oC

Peak Dust Loadings

Converter 1	8.14 g/Nm3
Scan Lance	5.77 g/Nm3
Roof Extraction	1.92 g/Nm3
Combined Total	8.14 g/Nm3

Fume Extraction, Fume Temperatures and Dust Loadings are shown in graphs overleaf.

Calc. No:	141325/003-0001	***All Normal Figures relate to 273K***			
Client	UNIDO	Prepared	P.Puntan	Date	12.03.97
Project	Dunaferr	Checked	[signature]	Job No	141325
Description	Option 2 "2/1" Operation - Calculation of Maximum Fume Extraction Volume			Sheet No	1

McLellan and Partners Ltd	Calculation/Design Sheet

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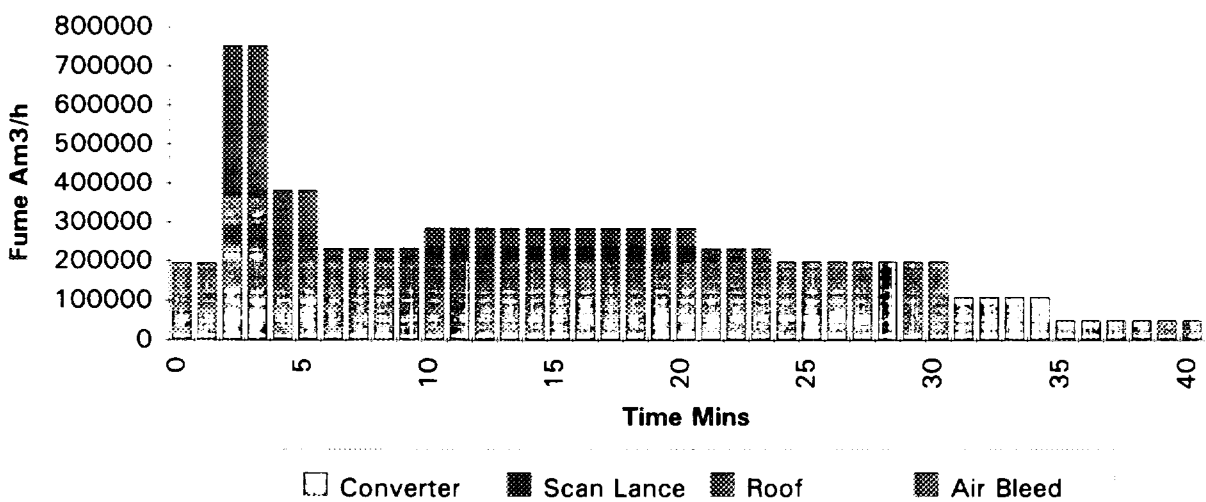
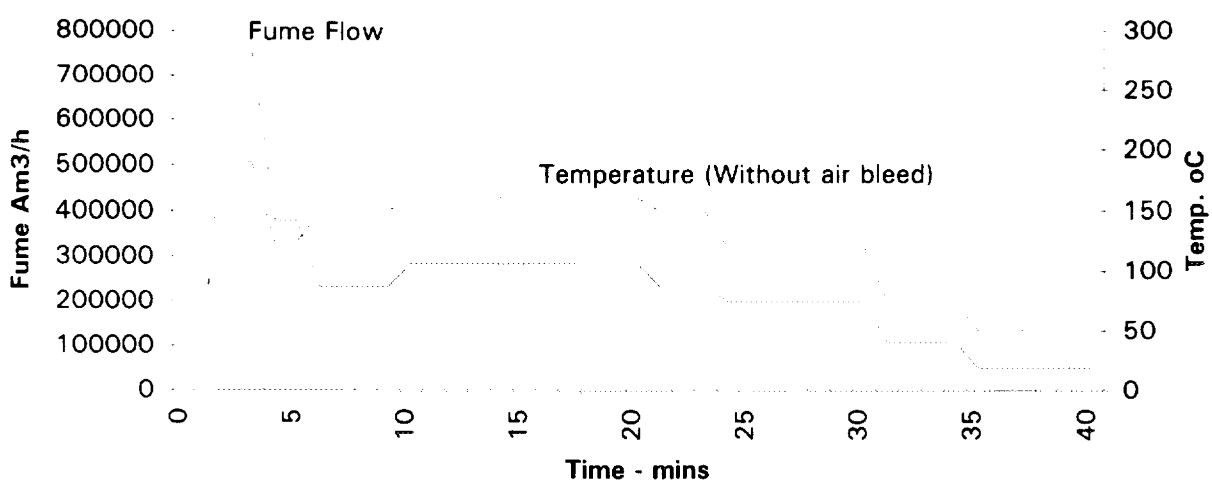
Calculation of Maximum Total Fume Generation and Temperature

Option 2 "2/1" Operation - Calculation of Maximum Total Fume Extraction



LD Converter Shop - Fume and Temperature Profile



Calculation No: 141325/003-0001	*All Normal Figures relate to 273K*	
Client UNIDO	Prepared P.Puntan	Date 12.03.97
Project	Checked [signature]	Job No 141325
Description Option 2 "2/1" Operation - Calculation of Maximum Fume Extraction Volume		Sheet No 2

McLellan and Partners Ltd	Calculation/Design Sheet

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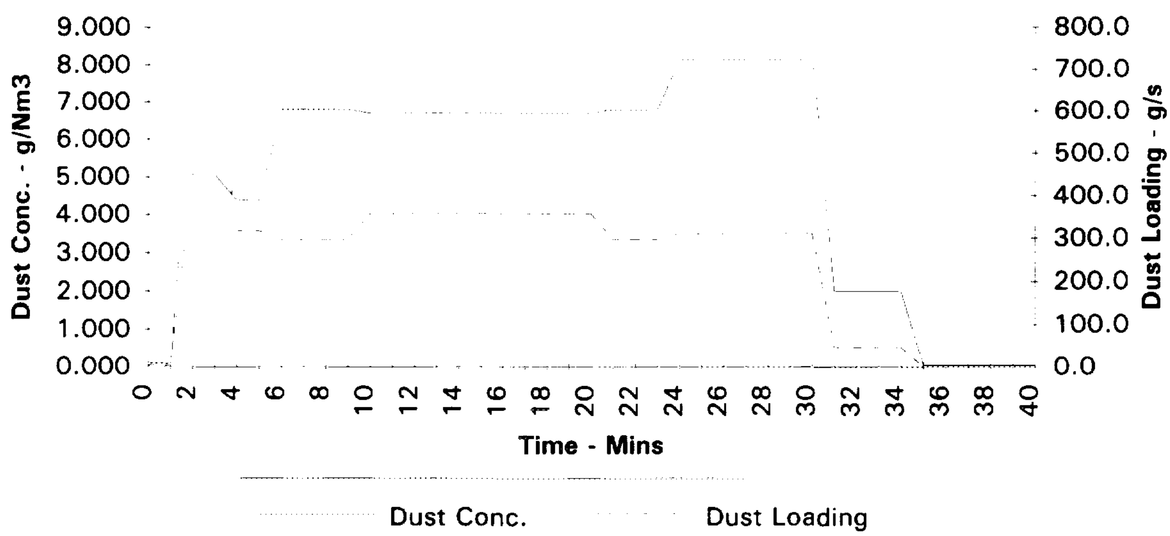
Dust Profiles - Merged Flows



Calculation No: 141325/003-0001		*All Normal Figures relate to 273K*			
Client	UNIDO	Prepared	P.Puntan	Date	12.03.97
Project		Checked		Job No	141325
Description	Option 2 "2/1" Operation - Calculation of Maximum Fume Extraction Volume			Sheet No	3

ANNEX 4

DRAWINGS

Drawing No	Drawn	Date	DO Chk	Date	Orig Chk	Date	App	Date	Revision
1415[illegible]/3'B'	AK	14.2.96	JC	9.5.96	PCP	9.5.96	AM	9.5.96	A: Flows and Temps. deleted.24.1.97; B: Title Modified.10.4.97

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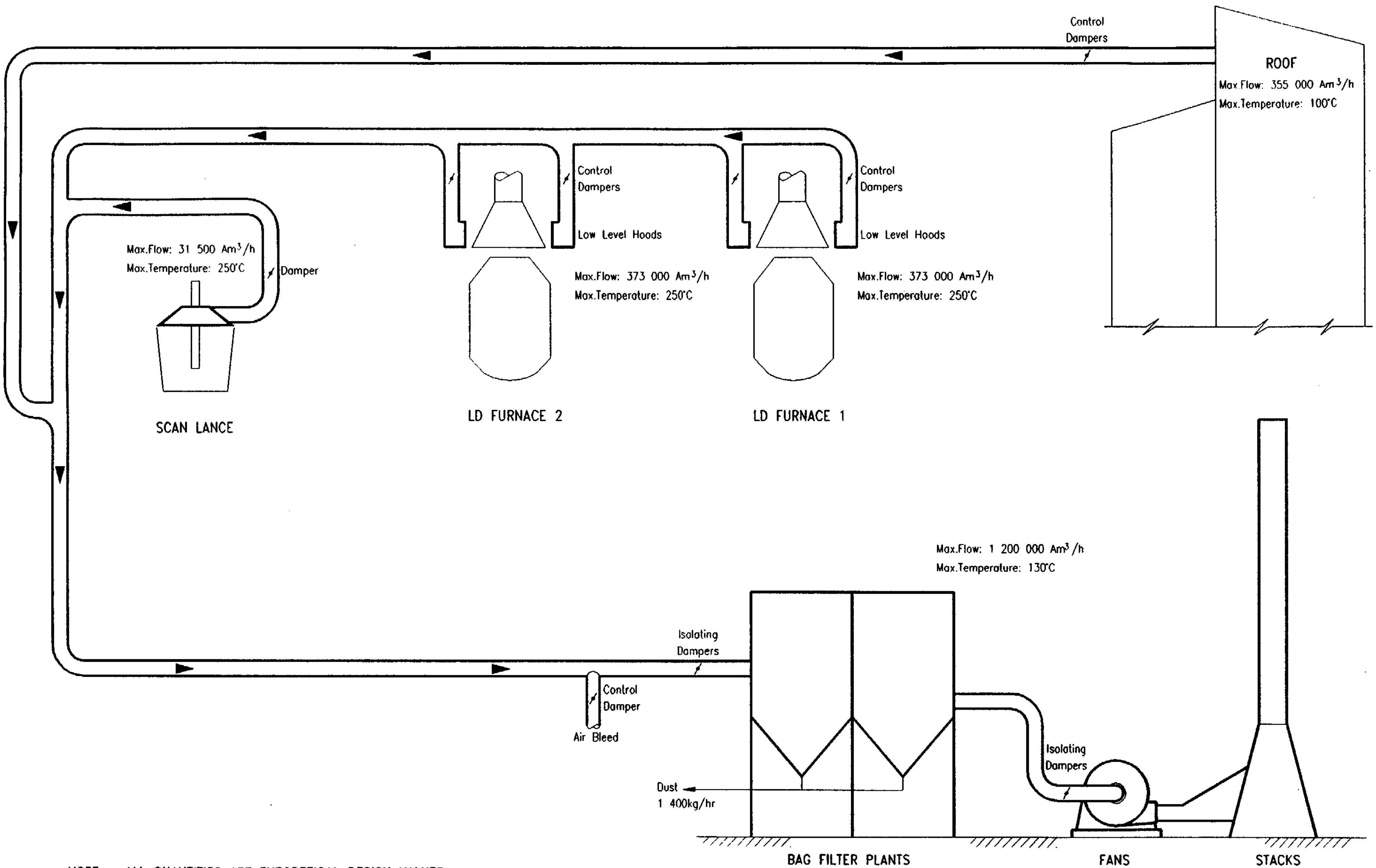

NOTE: ALL QUANTITIES ARE THEORETICAL DESIGN VALUES

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Project No TF/HUN/94/E90
Dunaferr Steelworks - Hungary

Secondary Fume Cleaning Design Study
Option 1-"2/2" Operation Process Flow Diagram

Figure
1.1

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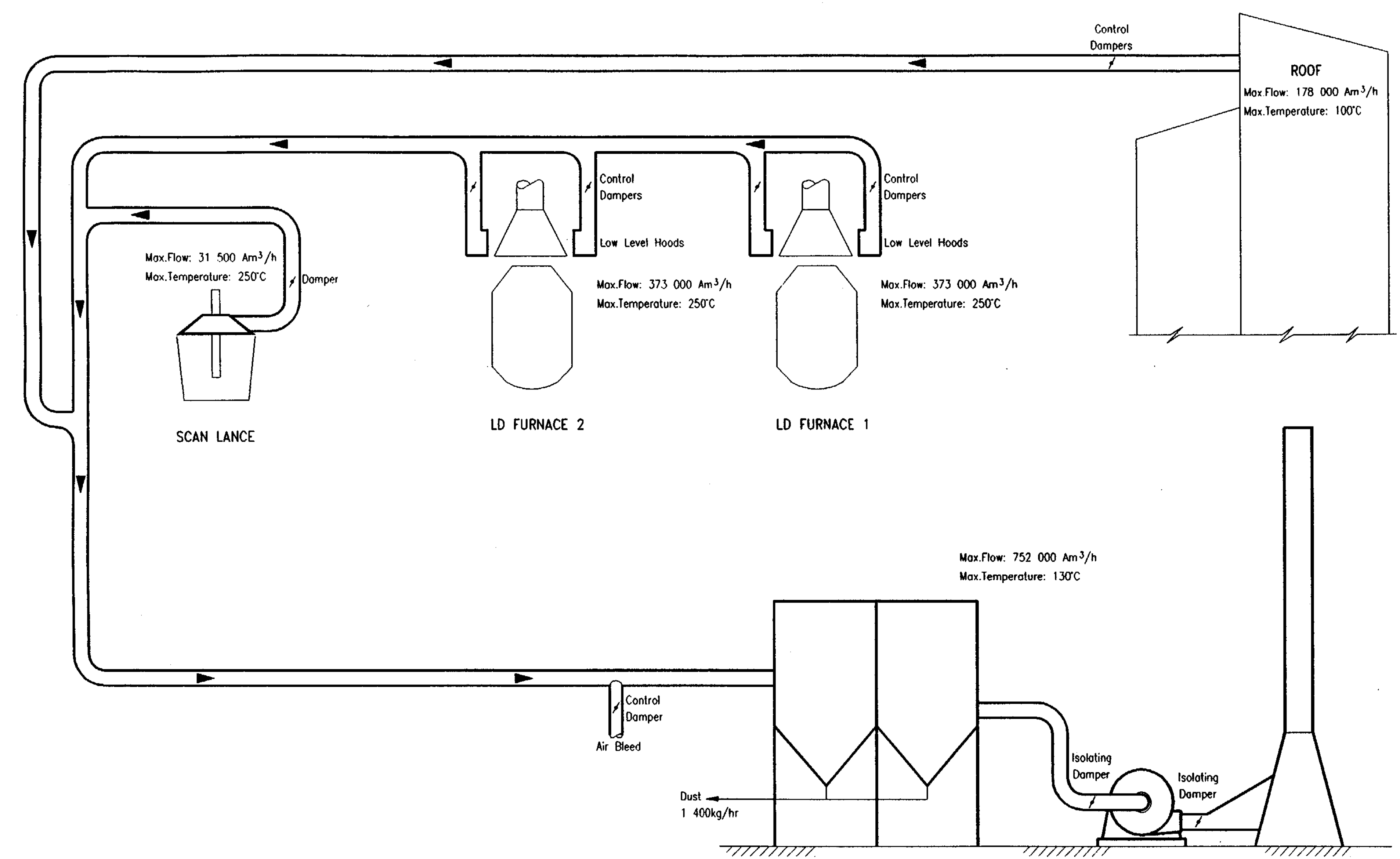

NOTE: ALL QUANTITIES ARE THEORETICAL DESIGN VALUES

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Secondary Fume Cleaning Design Study
Option 2-"2/1" Operation Process Flow Diagram

Figure 1.2

Drawing No	Drawn	Date	DO Chk	Date	Orig Chk	Date	App	Date	Revision
141325/12'A'	AK	18.4.96							A:10.4.97:TITLE MODIFIED

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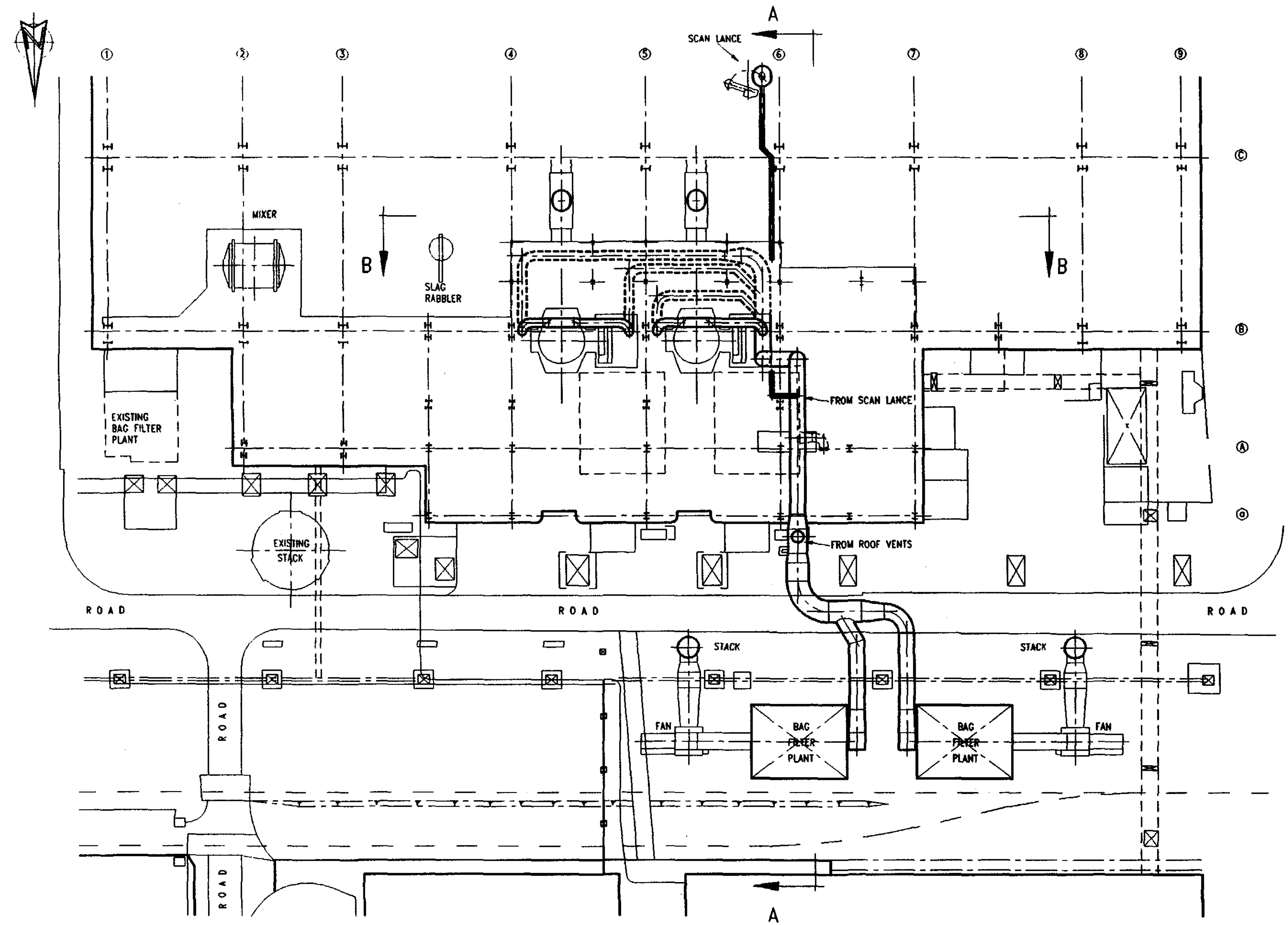

NOTE:-
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OPTION 1-"2/2" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
PLAN VIEW

Figure 2.1

Drawing No	Drawn	Date	DD Chk	Date	Orig Chk	Date	App	Date	Revision
141325/17'A'	AK	19.2.96							A:10.4.97:TITLE MODIFIED

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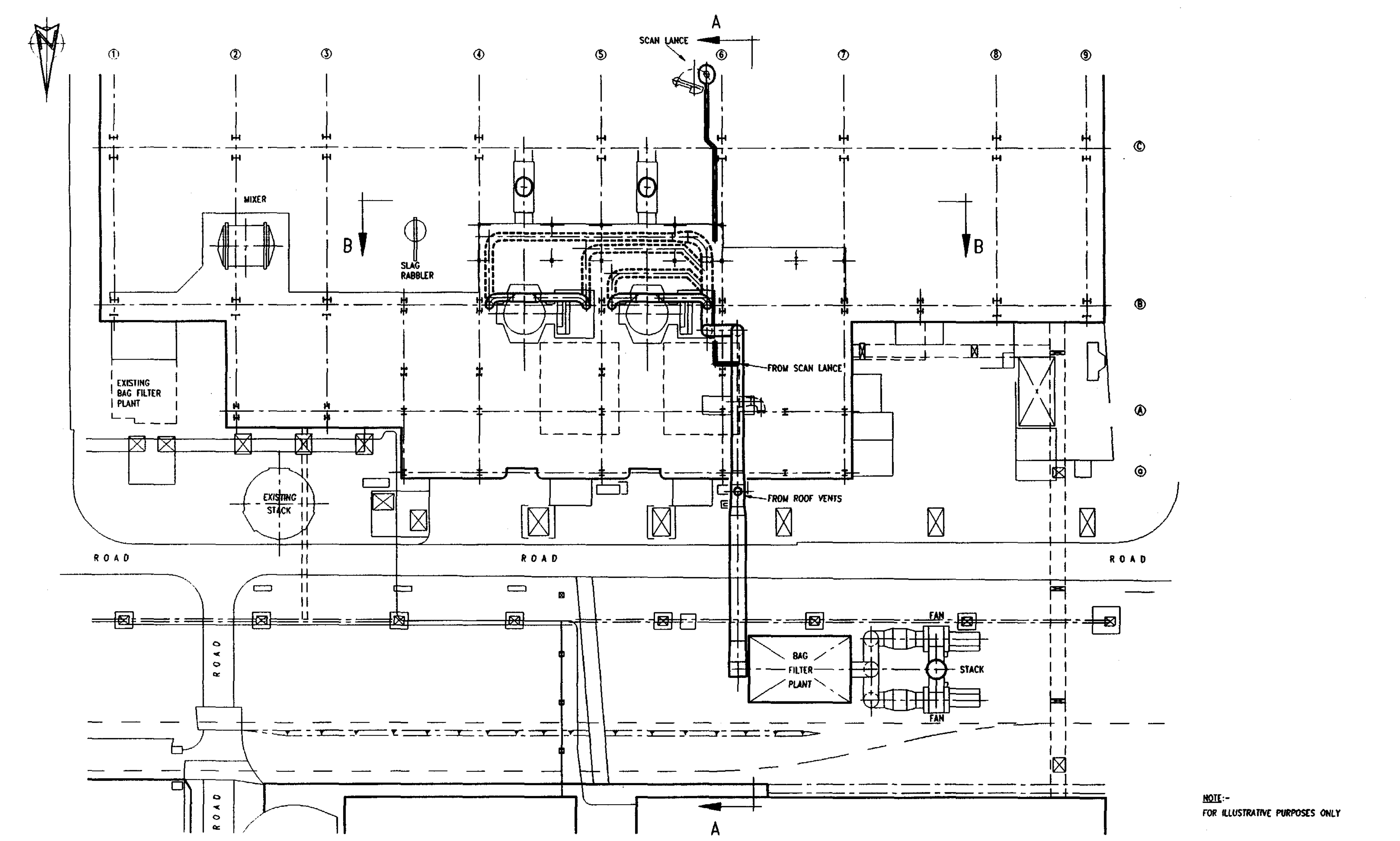

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OPTION 2-"2/1" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
PLAN VIEW

Figure
2.2

Drawing No	Drawn	Date	DO Chk	Date	Orig Chk	Date	App	Date	Revision
141325/9'A'	AK	18.4.96							A:10.4.97:TITLE MODIFIED

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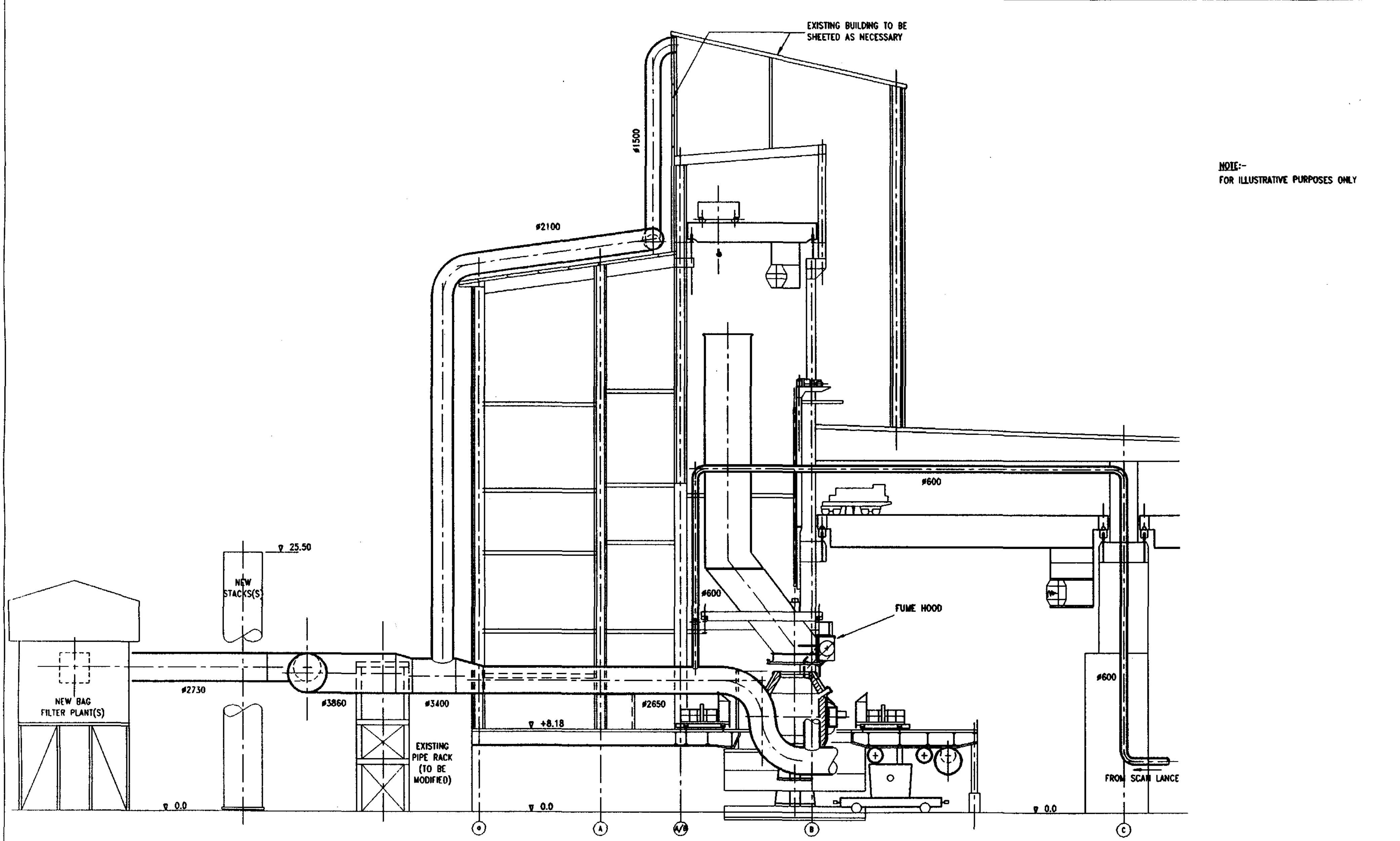

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OPTION 1-"2/2" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION A - A

Figure 3.1

141325/16'A' | AK | 19.2.97 | Revision A:10.4.97:TITLE MODIFIED

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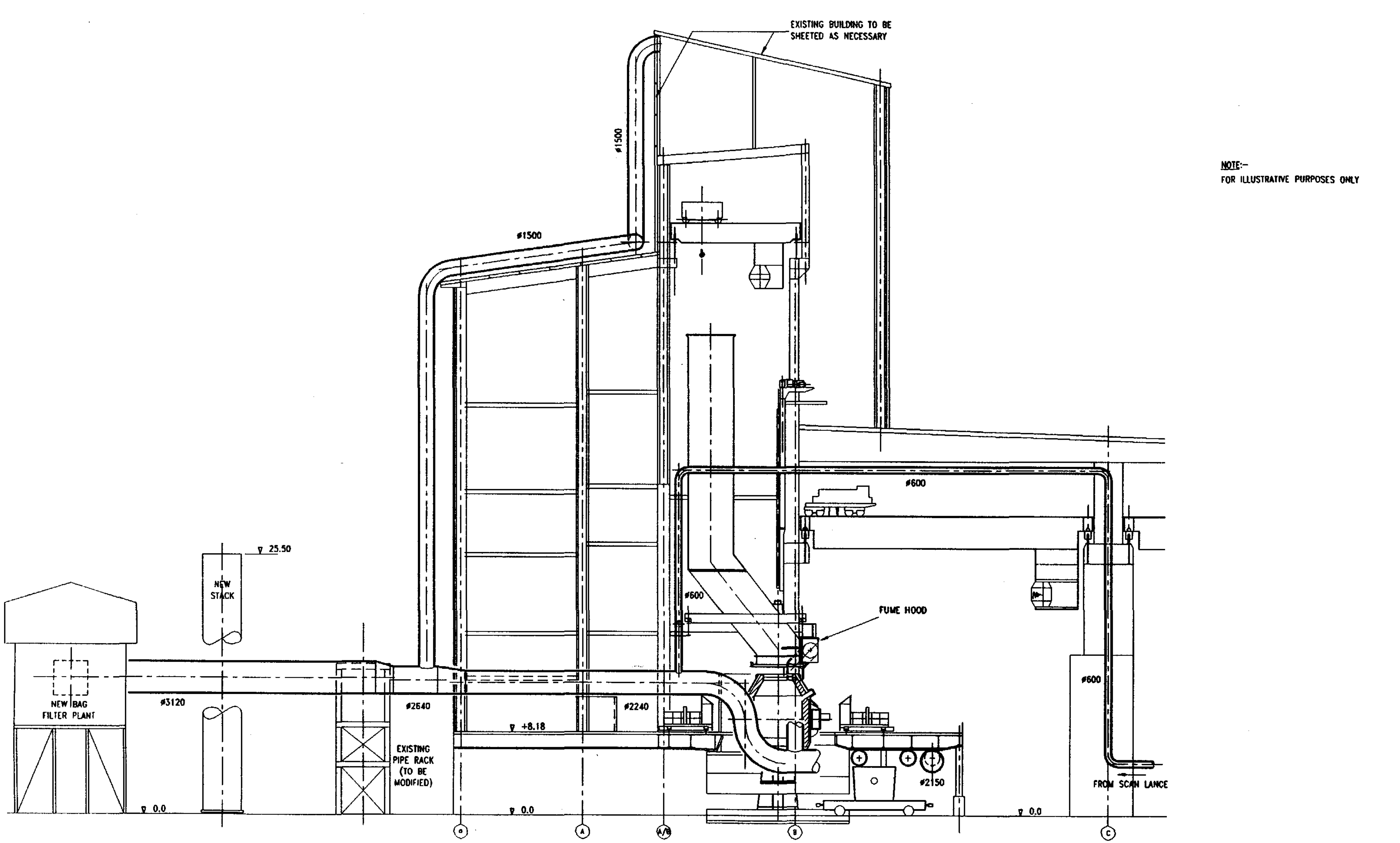

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OPTION 2–"2/1" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION A – A

Figure 3.2

Drawing No	Drawn	Date	BO Chk	Date	Orig Chk	Date	App	Date	Revision
141325/10'A'	AK	4.4.96		4.97					A:10.4.97:TITLE MODIFIED

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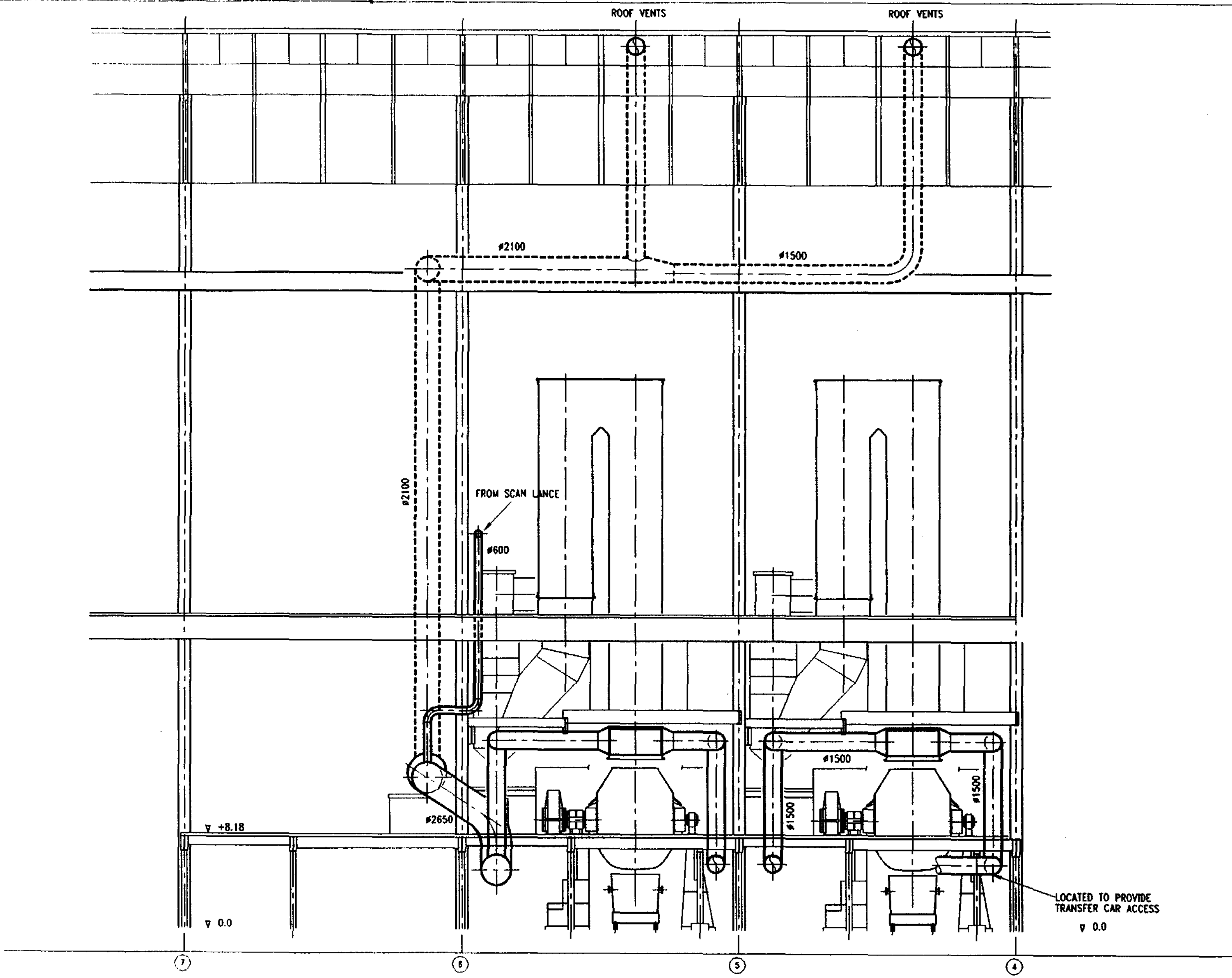

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OPTION 1-"2/2" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION B - B

Figure 4.1

Drawing No	Drawn	Date	DO Chk	Date	Orig Chk	Date	App	Date	Revision
141325/18	DKG	11.4.97		28.4.97					

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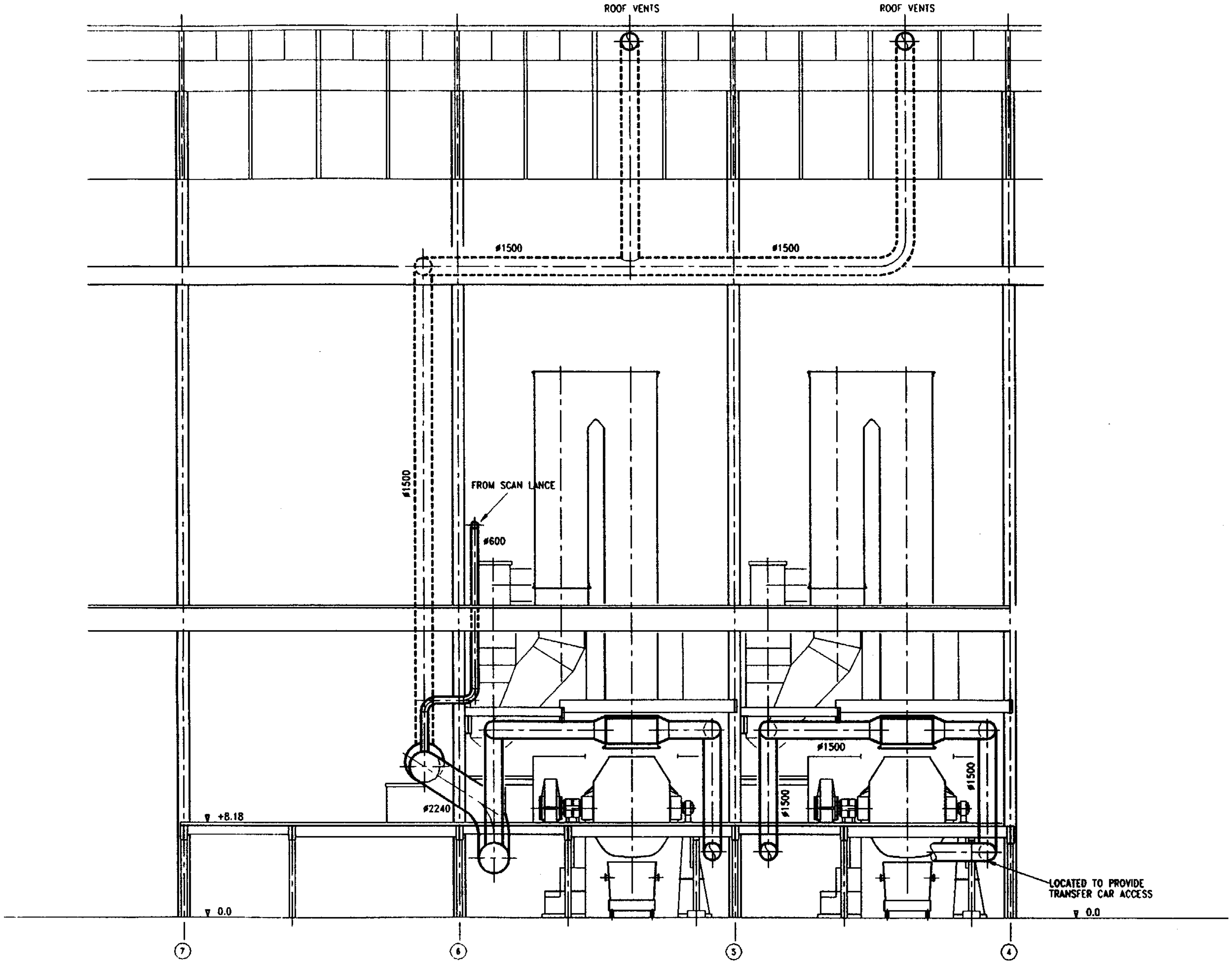

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OPTION 2-"2/1" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION B - B

Figure 4.2

141325/13'A' | AK | 18.4.96 | App | Date | Revision A:10.4.97:TITLE MODIFIED

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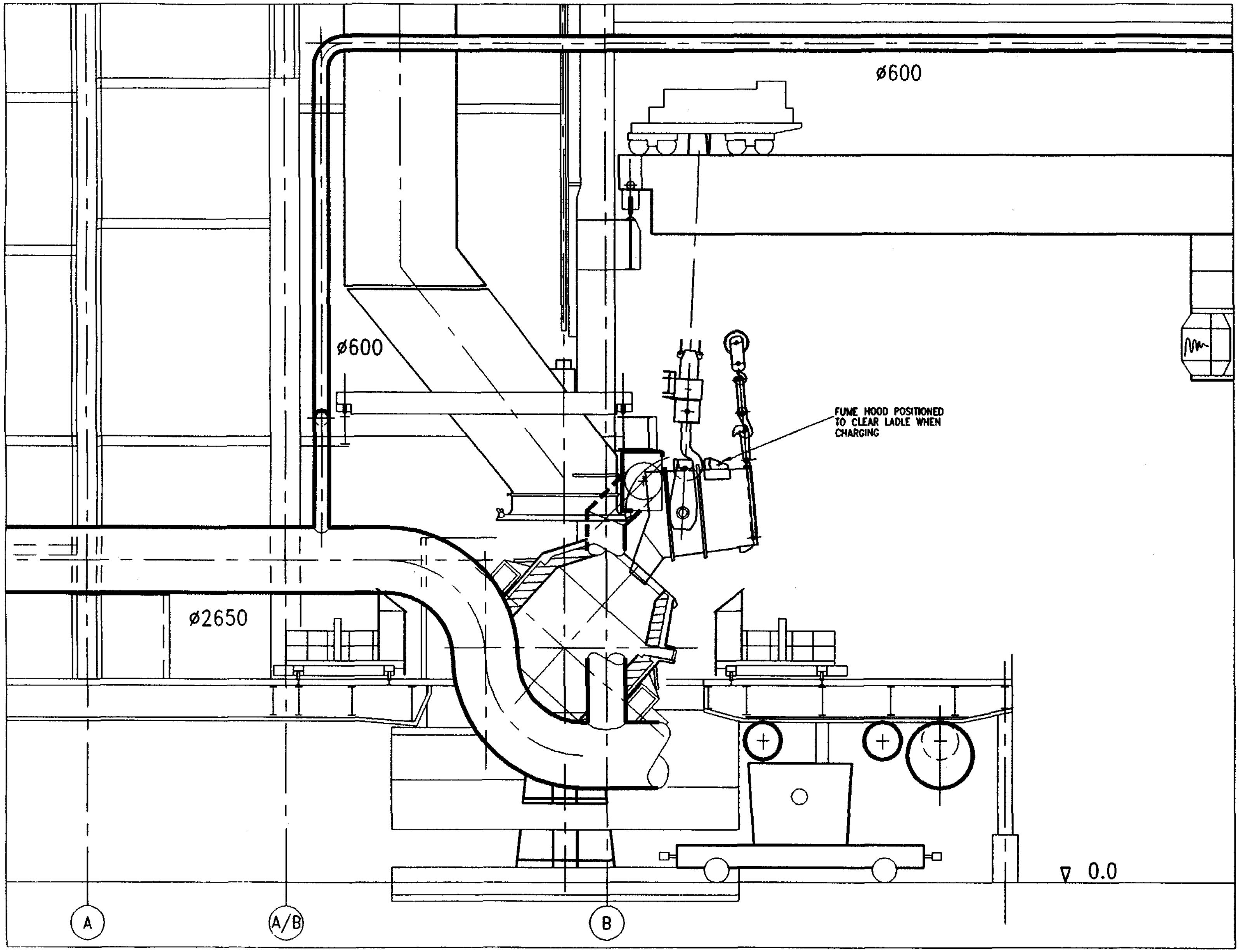

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Dunaferr Steelworks-Hungary

OPTION 1-"2/2" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION B - B

Figure
5.1

141325/19 | AK | 28.4.97 | 18.4.96

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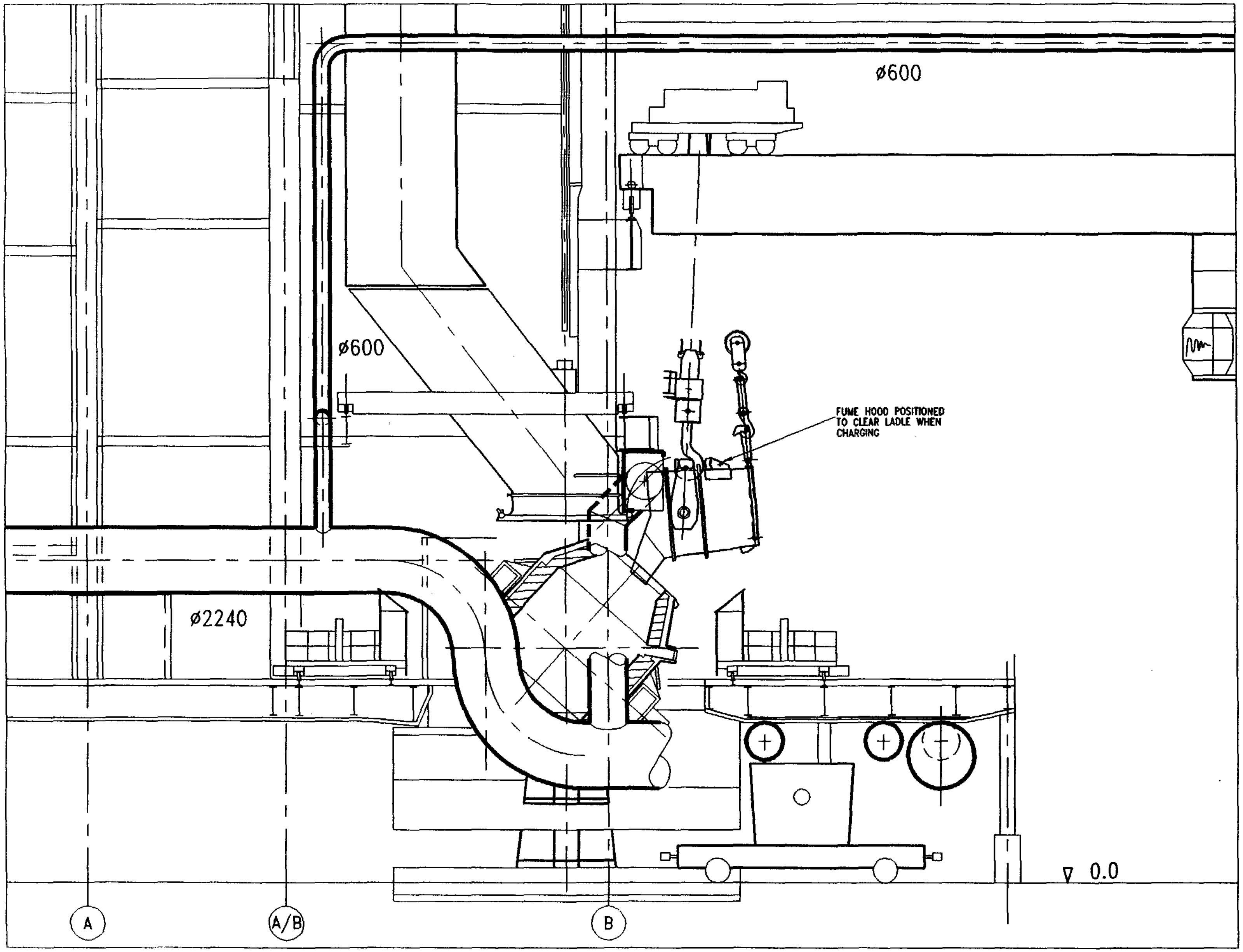

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OPTION 2-"2/1" OPERATION
PROPOSED SECONDARY FUME EXTRACTION SYSTEM
SECTION B - B

Figure 5.2

Drawing No	Drawn	Date	DO Chk	Date	Orig Chk	Date	App	Date	Revision
141325/20	DKG	23.4.97	[illegible]	28.4.97					

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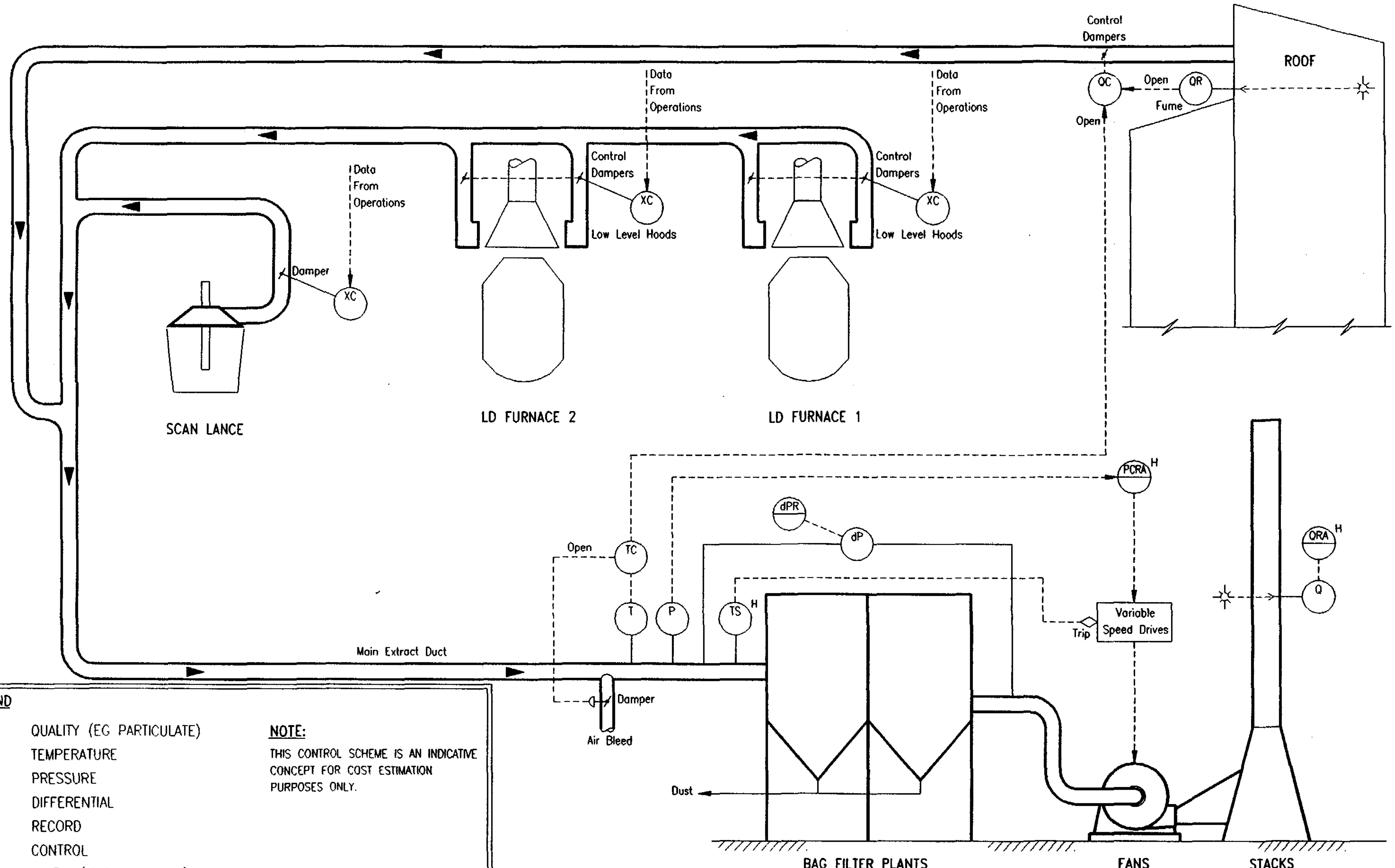

LEGEND

Q = QUALITY (EG PARTICULATE)
T = TEMPERATURE
P = PRESSURE
d = DIFFERENTIAL
R = RECORD
C = CONTROL
A = ALARM (H=HIGH L=LOW)

NOTE:
THIS CONTROL SCHEME IS AN INDICATIVE CONCEPT FOR COST ESTIMATION PURPOSES ONLY.

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Secondary Fume Cleaning Design Study
Indicative Concept of Control Scheme

Figure 6

ANNEX 5

PHOTOGRAPHS

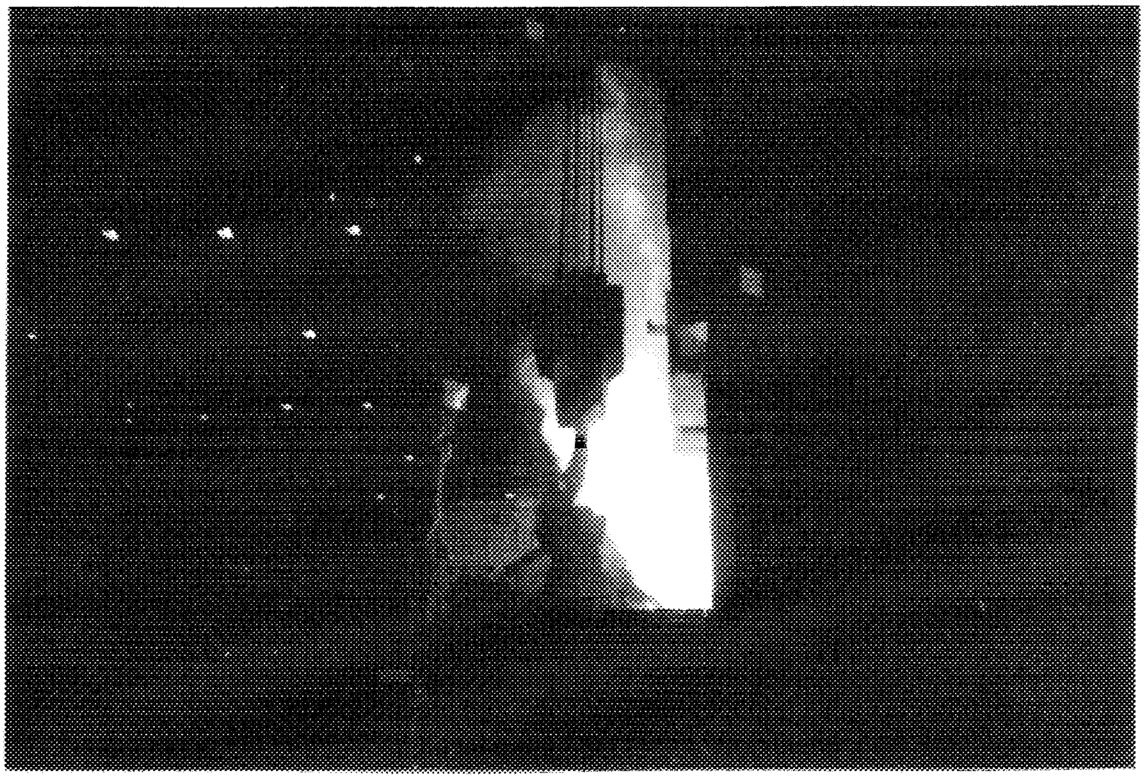


Plate 1: LD Converter Fume Generation During Hot Metal Charging

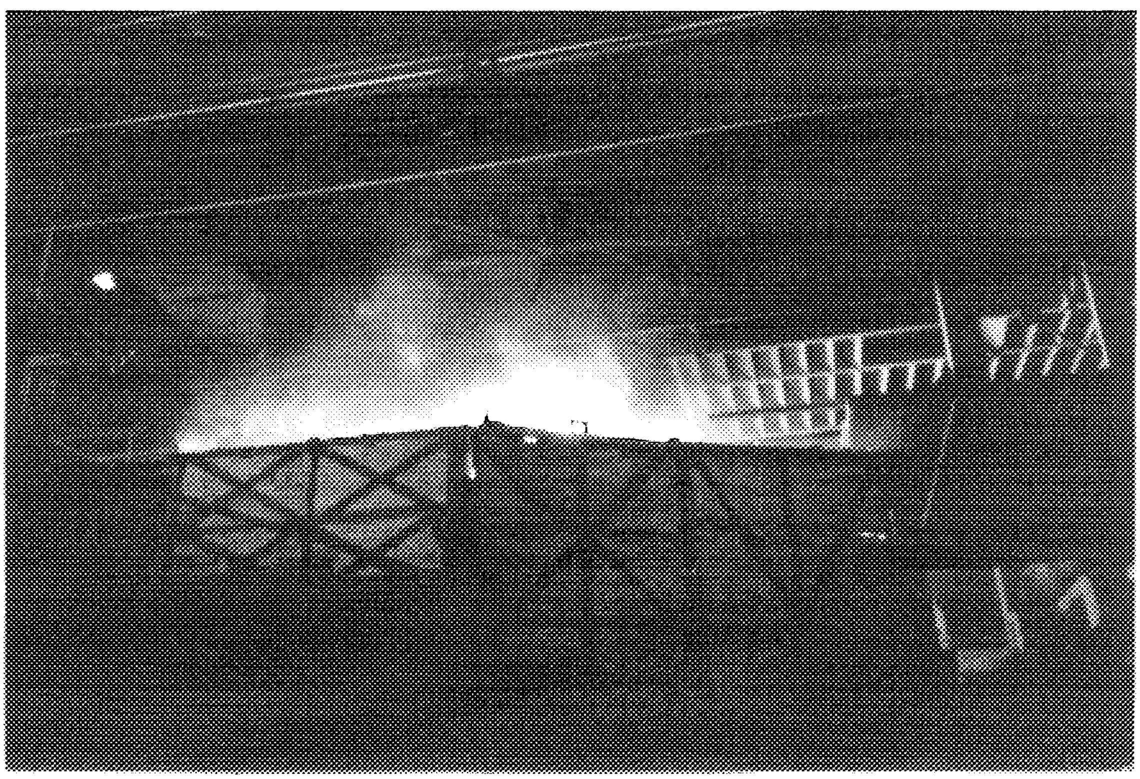


Plate 2: LD Converter Fume Generation During Blowing

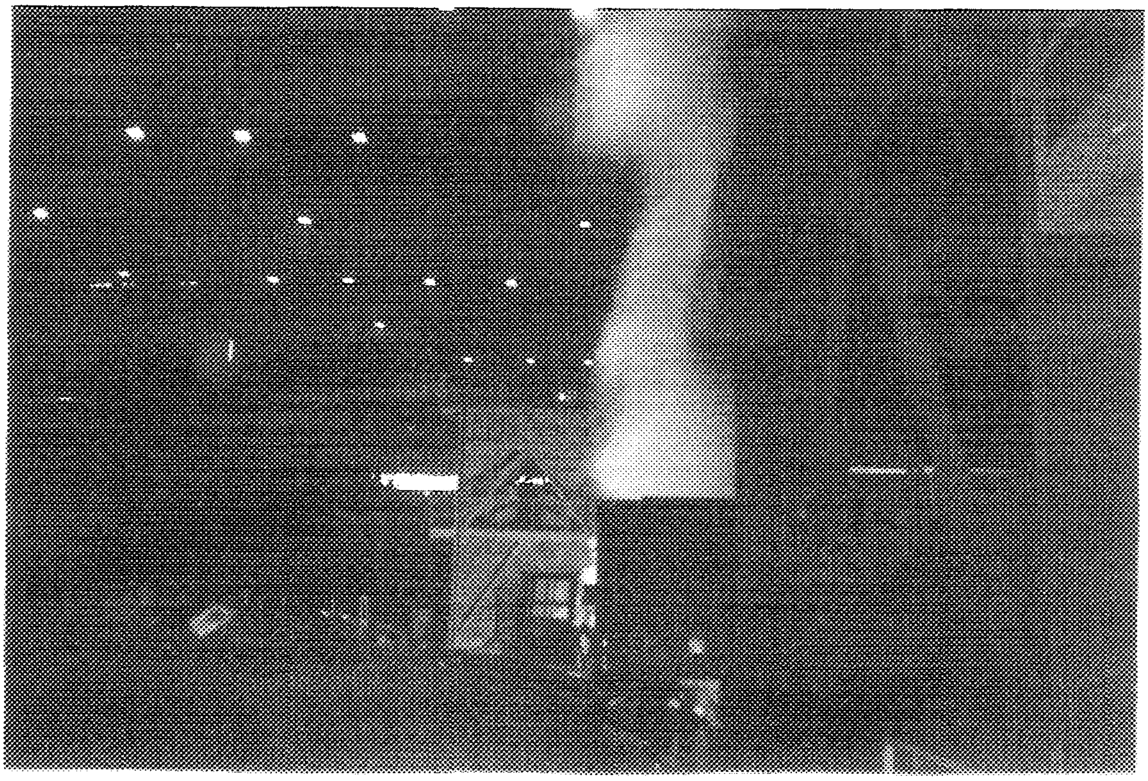


Plate 3: LD Converter Fume Generation During Metal Tapping

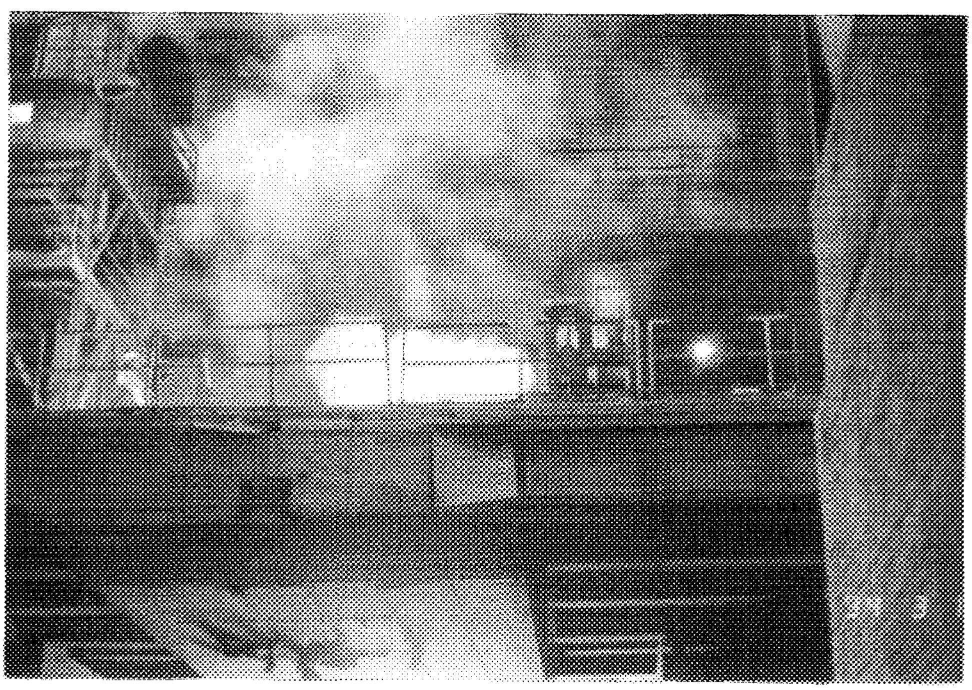


Plate 4: LD Converter Fume Generation During Metal Tapping

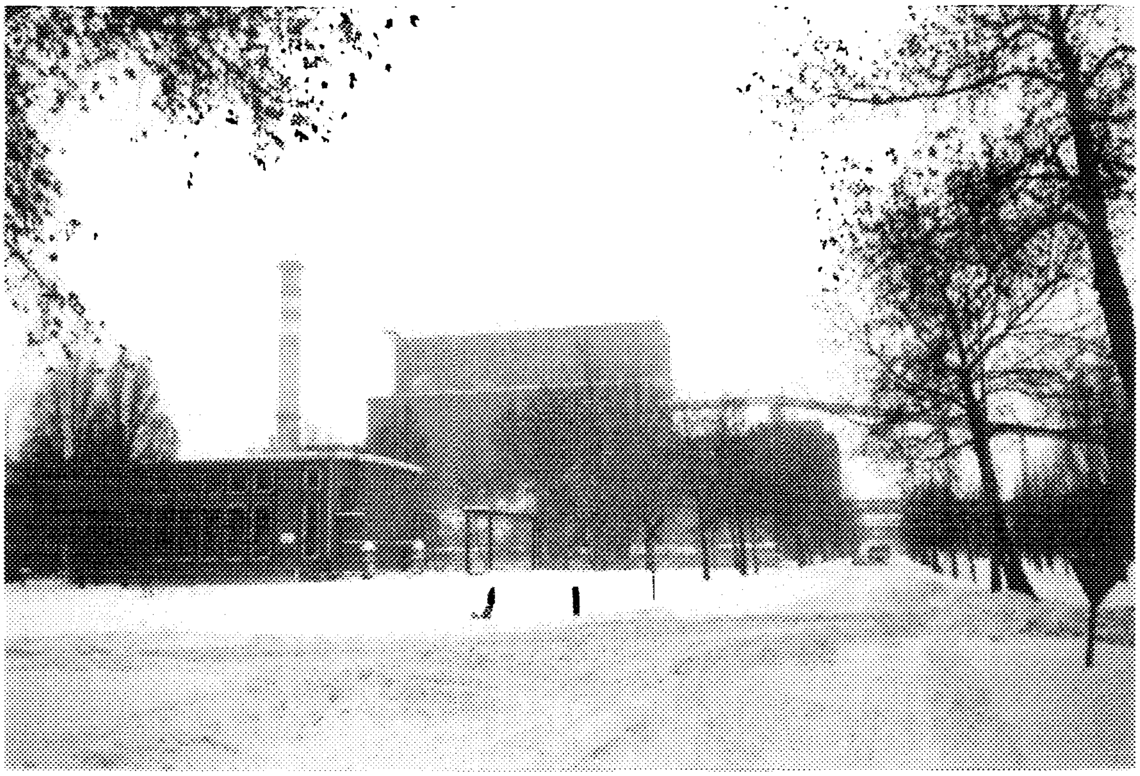


Plate 5: Fume Emissions from Steel Shop Building

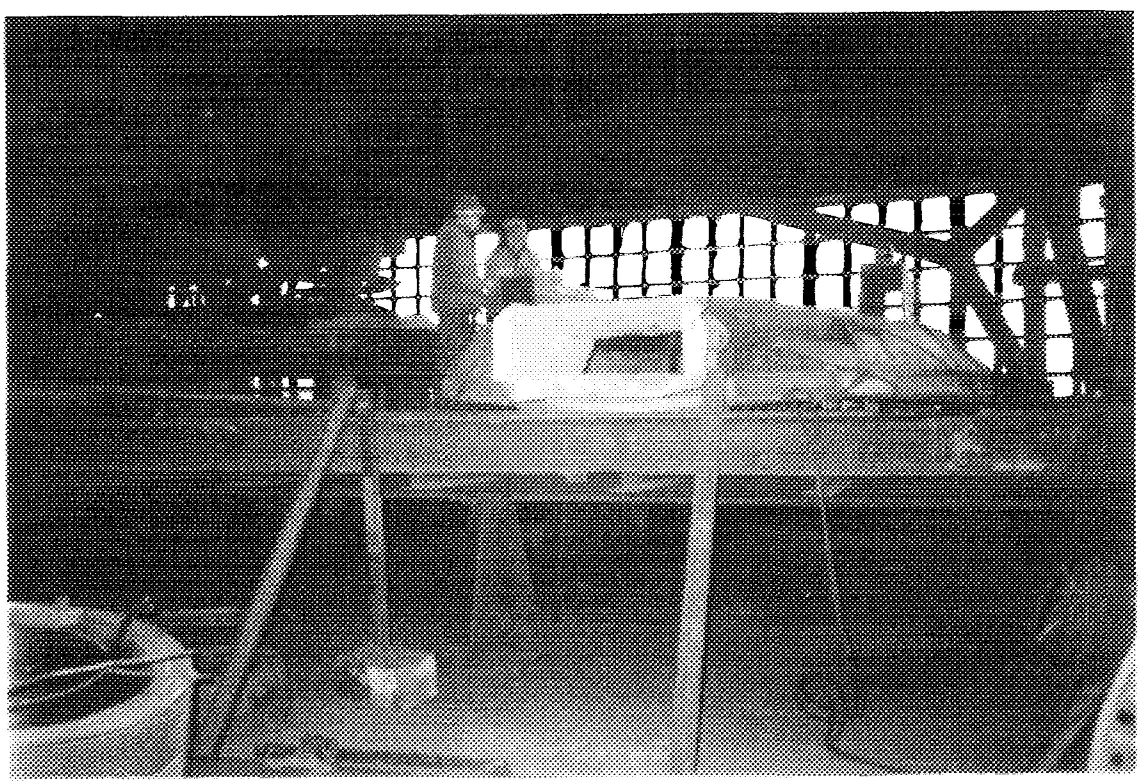
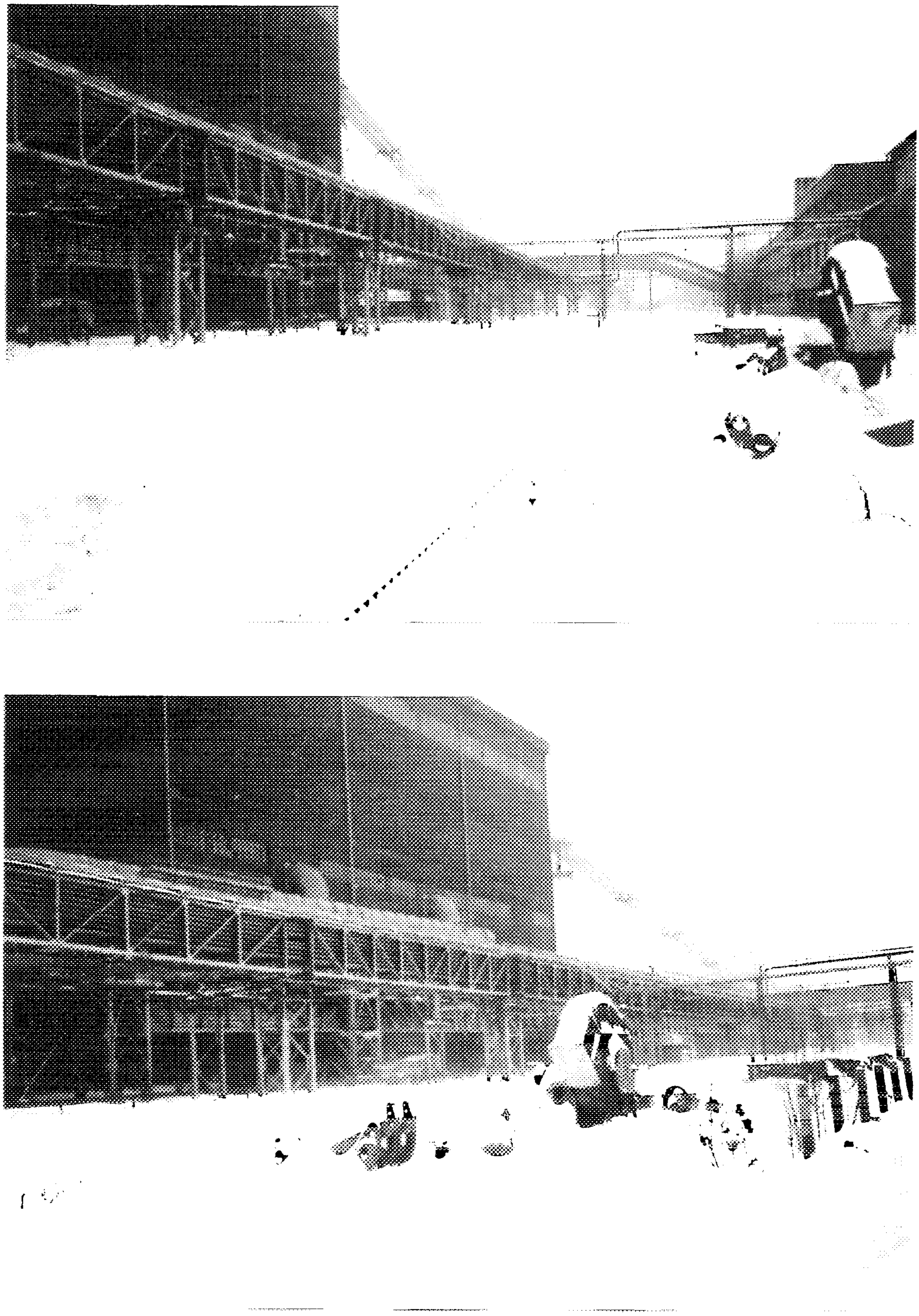


Plate 6: Scan Lance Roof During Maintenance - Showing Rear Extraction Port



Plates 7 & 8: Proposed Location of Fabric Filters and Associated Equipment

McLellan

Consultants

Engineers

Project Managers

McLellan and Partners Limited

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