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ENVIRONMENTAL SURVEY & RECOMMENDATIONS
FOR
ELFOULADH
SOCIETE TUNISIENNE DE SIDERURGIE
MENZEL BOURGUIBA, TUNISIA

SUBMITTED BY

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WORLD ENVIRONMENT CENTER

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PREFACE

This report -- prepared by the Koppers Co. of Pittsburgh, U.S.A. -- is hereby transmitted by the World Environment Center to the Government of Tunisia.

It is the result of a detailed survey of the ELFOULADH steel complex (Societe Tunisienne de Siderurgie), Menzel Bourguiba, Tunisia, by M.G. Morris, Manager, Air Quality Engineering and E.F. Harchelroad, Staff Engineer. The Center wishes to express its deep appreciation to the Koppers Co. for making their services available for this project. The report itself is of the highest professional quality and should be of great value to the Tunisian authorities and plant management in mitigating adverse environmental impacts at ELFOULADH.

The Koppers mission to Tunisia was carried out under a new program of the Center, the U.S. Agency for International Development and American industry. It provides technical assistance to developing countries to help them solve their industrial pollution problems. U.S. companies provide the services of experts free of charge to eligible countries requesting assistance as a voluntary contribution to improving the quality of life in those countries.

The World Environment Center is a not-for-profit information and education service on international environmental issues. It was established in 1974 with funding from the United Nations Environment Program (UNEP). The Center has overall planning and administrative responsibility for the technical assistance program.

Information on the Report Authors

Emmet F. Harchelroad is an engineer with 33 years of experience in the engineering, design, construction and administration of steelmaking and aluminum industry facilities. He is presently a staff engineer coordinating engineering design service contracts with Koppers' Engineering and Construction Group. He holds a Bachelors Degree in Mechanical Engineering from Carnegie Mellon University (Carnegie Institute of Technology). His experience includes work as Senior Project Engineer for integrated steelmaking facilities in Eregli, Turkey and Pohang, Korea. His experiences also include Acting Resident Manager of Construction at Eregli, Turkey in 1978 and 1979.

In relation to this report, Mr. Harchelroad has extensive experience in preparation of technical specifications for engineering, design and construction of blast furnaces, basic oxygen furnace shops, continuous billet casters, electric furnace shops, hot and cold rolling facilities and general plant facilities.

Miles G. Morris is a professional engineer with 31 years of industrial experience. He is presently Manager of Air Quality Engineering, Environmental Resources Department of Koppers Company, Inc. He holds a Master of Science Degree in chemical engineering from the University of Pittsburgh, and is a licensed Professional Engineer. He is a member of the American Institute of Chemical Engineers and the Air Pollution Control Association.

In relation to this report, Mr. Morris has 20 years in the engineering and construction of chemical and steel plants in the United States and South America, and 11 years of involvement with environmental problems of chemical, steel and synthetic fuel plants in America and Spain.

Koppers Company, Inc., Pittsburgh, PA 15219
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KOPPERS

Alonzo Wm. Lawrence, Ph.D.
Vice President
Science and Technology

December 30, 1982

Dr. Ali Ben Gaied
Director
Office of Environment Standards
and Quality Control
Ministry of National Economy
Government of Tunisia
Tunis, Tunisia

Dear Dr. Gaied:

Attached is a report which is the result of a visit by Emmert F. Harchelroad and Miles G. Morris on October 26 through October 28, 1982 to the ELFOULADH Steel-making Facility. On behalf of Messrs. Harchelroad and Morris and Koppers Company, Inc., I extend to you my personal thank you for the hospitality which was extended during the visit.

In our report, we have examined current operating activities at ELFOULADH and have endeavored to suggest changes and programs which will improve the environmental quality in and around the facility. I sincerely hope that our visit, and this report will provide you with additional information with which to advance the environmental program in Tunisia.

Sincerely yours,

Alonzo Wm. Lawrence

Alonzo Wm. Lawrence

Attachment

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ACKNOWLEDGEMENT

The preparation of this report, covering the environmental survey and recommendations for the ELFOULADH Steel plant at Menzel Bourguiba, Tunisia, was preceded by the work of others who initiated the program and planned the agenda for the visit to the steel plant. The authors of this report wish to acknowledge the assistance of the World Environment Center, US Agency for International Development and the following individuals for their assistance in the performance of the task:

Dr. Ali Ben Gaied, Director of Environmental Standards and Air Quality Control and his assistant Mr. Bouraoui Darmoul of the Ministry of National Economy and their staff for arranging the visit and presenting Tunisia's position on environmental issues.

Mr. Abou Baker Zaak, President-Director General (PDG), of ELFOULADH Steel Company and his staff for their complete cooperation during the observation of the plant operations and for providing engineering data and drawings which were essential for the preparation of this report of the environmental aspects of the steel plant.

Mr. Richard Stevenson of the US Agency for International Development and his staff for their guidance and logistical support to facilitate the successful accomplishment of our mission.

DISCLAIMER

The technical advice and services provided to the Government of the Republic of Tunisia (Tunisia) and its agents during the period May 1, 1982, through December 31, 1984, by experts from United States institutions working under the sponsorship of the World Environment Center of New York, New York, U.S.A., was and is to be furnished on a free-of-charge basis to Tunisia. As a result, the World Environment Center, the experts provided by it, and their United States institutions hereby disclaim any legal responsibility and liability, whether under the laws of Tunisia, the United States, or any other jurisdiction, vis-a-vis Tunisia, its agents and its residents for the advise and services provided by such experts (which advice includes explicit and implicit suggestions and the omission of suggestions).

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Executive Summary

Koppers Company, Inc. of Pittsburgh, Pennsylvania, USA, is a participating member of the World Environment Center's International Environment & Development Service to assist developing countries with their industrial pollution problems.

At the request of the Center and the US Agency for International Development, Koppers Company, Inc. sent two senior engineers to make suggestions for environmental improvement at the ELFOULADH steel plant Menzel Bourguiba, Tunisia. ELFOULADH is a complex integrated steel plant producing rod, galvanized wire and structural pylons. The plant survey occurred on October 26 through October 28, 1982.

The ELFOULADH steel plant has the potential for the same environmental impact which exist at any integrated steel plant of its size and finished product mix. At the present time in Tunisia, there are few governmental regulations or guidelines to control the discharge of pollutants and solid wastes to the atmosphere, receiving waters and landfills. Although ELFOULADH is under little regulatory pressure to control emission sources, the plant management is generally aware of the environmental problems and has with limited financial resources, made efforts to minimize the plant's adverse environmental impact.

In most instances, the plant has been provided witn basically sound air pollution control and water treatment systems, needing in some cases, only a relatively minor upgrading to improve performance. There are, however, several large sources in the plant which are considered to be first priority items for the installation of environmental controls. These are the two LD furnaces and the electric arc furnace which were installed without any particulate control equipment. The emission from these furnaces are no doubt adversely impacting the surrounding area, Lake Bizerte, and the town of Menzel Bourguiba. The particulate from these sources is even adding considerable solids to the steel plants recirculated water systems.

Technology has been available for control of particulate emissions from these furnaces since their inception. It is interesting to note that one internationally accepted reference source states that there are only three LD furnaces in the world which were built without dust control, two of these are at ELFOULADH[1].

Control equipment recommendations, for the LD furnaces and the electric arc furnace, are discussed in Section 3.2 of the report. The recommendations are only tentative since it is obvious that a final decision must be based on a thorough engineering and cost study. A detailed analysis such as this is not within the scope of this report.

The alternate control technologies, for the LD furnaces, are electrostatic precipitators or a hi-energy venturi scrubbers. Due to the high temperature of the LD furnace off-gas from the combustion zone, a baghouse is not a feasible selection. An electrostatic precipitator is selected as the preferred control device based on generalized cost data indicating lower installed and operating costs. An electrostatic precipitator for ELFOULADH's furnaces would cost in the USA in the range of from $500,000-$750,000 (equipment only).

The alternate control technologies for the electric arc furnace are electrostatic precipitator, a hi-energy venturi scrubber, or a baghouse. A baghouse is selected as the recommended control device based on the cost data referred to above. The cost in the USA of a baghouse for ELFOULADH would be in the range of $100,000-$200,000 (equipment only).

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[1]Adams, R. W. 1982. BOF Steelmaking: A publication of the Iron and Steel Society of the American Institute of Mining, Metallurgical & Petroleum Engineers, Warrendale, PA USA 15086, Volume Two, Chapter 10, p. 648.

Several other options for furnace control are presented in the report. These include a suggestion to consider the installation of one large precipitator to handle the waste gases from all of the furnaces. The precipitator size will depend on the mode of operation of the furnaces. Evaluation of the feasibility of using mechanical collectors as the first phase of a two phase control program is suggested. Each of these options would require a detailed study.

This report covers other areas of environmental concern and a number of suggestions and recommendations are presented. The desirability of instituting a monitoring program for air and water to establish the present baseline is also reviewed and a preliminary plan outlined. Monitoring information would be of particular value for ELFOULADH, since it is essentially an isolated source. The data generated would reflect the plant's impact. Comparison of this information with recognized criteria would indicate the magnitude of the problem, and would provide valuable control design information.

1.0 Introduction

The purpose of this report is to present the results of an environmental survey made at the ELFOULADH steel plant located at Menzel Bourguiba, Tunisia. The survey covered the impact of the plant operations on air, water, solid waste disposal, and safety and industrial hygiene.

Visits were made to the plant on October 26, 27, and 28, by Mr. Emmet Harchelroad and Mr. Miles Morris, engineers from Koppers Company, Inc. On the initial visit to the plant, Koppers engineers were accompanied by engineers from Dr. Ali Ben Gaied's staff and Dr. Whitman Bassow and Dr. Gene Wailen of the World Environment Center and US AID, respectively. Mr. Abou Baker Zaak, President-Director General, PDG, conducted the plant tour.

Koppers Company, Inc. is a diversified manufacturing corporation with specialized engineering and construction capabilities. Headquartered in Pittsburgh, Pennsylvania, USA, it has more than 250 operating locations and makes more than 100 types of products. Koppers is one of the world's largest designers and builders of basic steel plants, including coke ovens and related by-product chemical plants, continuous casting installations, sinter plants and pollution control equipment for the steelmaking process. The Engineering and Construction Group is also presently engaged in the engineering and development of a synthetic fuels plant to produce 200,000 gallons per day of fuel grade methanol.

The diversity of Koppers' operations affords its environmental and occupational health staff a wide range of technical and scientific interfaces, enlarging its knowledge base and improving its ability to provide expertise to economically solve many difficult environmental problems.

Messrs. Harchelroad and Morris utilized the expertise of a number of people in the Engineering and Construction Group and the Environmental Resources Department in the preparation of this report. Individuals who

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made significant contributions included Dr. Andrew C. Middleton, V.P. Environmental Resources; John R. Smith, Manager of Water Quality Engineering; Charles P. Brush, Manager of Environmental Planning; Charles W. Flickinger, Manager of Industrial Hygiene; Elizabeth A. Millard, Air Quality Engineer; William L. Gleason, Pollution Control Sales Engineer; and Gregory J. Emish, International Sales ENgineer.

It is Koppers' sincere desire that the report will be useful to all concerned in the efforts being made by the Tunisian government to minimize the environmental impact of industrial development.

2.0 Process Description

ELFOULADH is an integrated steel plant producing reinforcing rod, wire rod, wire with a variety of finishes such as bright basic, black annealed, galvanized and copper coated and galvanized pylons fabricated from round bar. The raw materials consist of local Tunisian ore and limestone and imported coke, all delivered to dockside on Lake Bizerte. Scrap comes from revert scrap, local Tunisian sources and a small amount which is imported. Main production units are:

One (I) sinter plant	160,000 metric tonne per year
One (I) 4 M blast furnace	150,000 metric tonne per year
One (I) pig machine	
Two (2) 20 tonne LD converters	140,000 metric tonne per year
One (I) 15 tonne electric arc furnace	40,000 metric tonne per year
Three (3) two strand continuous casting machines for 105 mm billets	80,000 metric tonne per year
One (I) bar mill	20,000 metric tonne per year
One (I) wire mill	60,000 metric tonne per year
One (I) wire mill for less than 5 mm	25,000 metric tonne per year
One (I) structural fabrication shop	10,000 metric tonne per year

In addition to the rod which is produced within the plant, approximately 100,000 tonnes is imported for the wire machine producing the under 5 mm wire size and for bar rod.

Supporting facilities include the power house with a turbo-blower and turbo-generator, an oxygen plant, lime kiln and various maintenance shops.

3.0 Environmental Evaluation

3.1 General

The environmental evaluation which is presented in the following section of the report describes the problem areas, discusses the control technologies which are available and provides control recommendations.

Equipment cost estimates are given for the recommended approach. However, these estimates should be considered very preliminary. They are included to give the relative magnitude of the cost for pollution control equipment, and do not include site specific costs such as ductwork modifications, piping, foundations and/or supports, electrical equipment or installation labor. Additional data and a detailed engineering study are required to develop a complete cost estimate. It should be realized that the installed costs may be several orders of magnitude greater than the cost shown in this report.

3.2 Air

3.2.1 General

The very nature of the iron and steelmaking operation is particularly conducive to the generation of particulate matter which is dispersed into the surrounding atmosphere, unless equipment is installed to reduce the volume of emissions and to capture that which is generated. Particulate emissions begin with the receipt of the raw materials--iron ore, coke, limestone, and sinter. These materials, when unloaded and at each transfer area, will separate according to size and the finer particles will become airborne. During the casting operation at the blast furnace, kish and particulate are generated as the molten iron combines with the oxygen in the air as it flows along the runners and into the ladle car. Slag flowing into a dry pit is also a source of particulate emission. A furnace slip which causes the bleeder valves to open will propel smaller coke, ore and sinter and limestone into the atmosphere.

The steelmaking operation is an area where large volumes of particulate are generated particularly during the oxygen blow at the LD furnaces and the meltdown and refining with oxygen lancing at the electric arc furnace. The transfer of the molten steel from the furnaces to the ladles will create some pollution.

The sinter plant and lime kiln can each be a major source of air pollution if they are not equipped with pollution control devices which are properly operated and maintained. The sinter plant is controlled with an electrostatic precipitator which appeared to be operating satisfactorily. The lime kiln area was not visited.

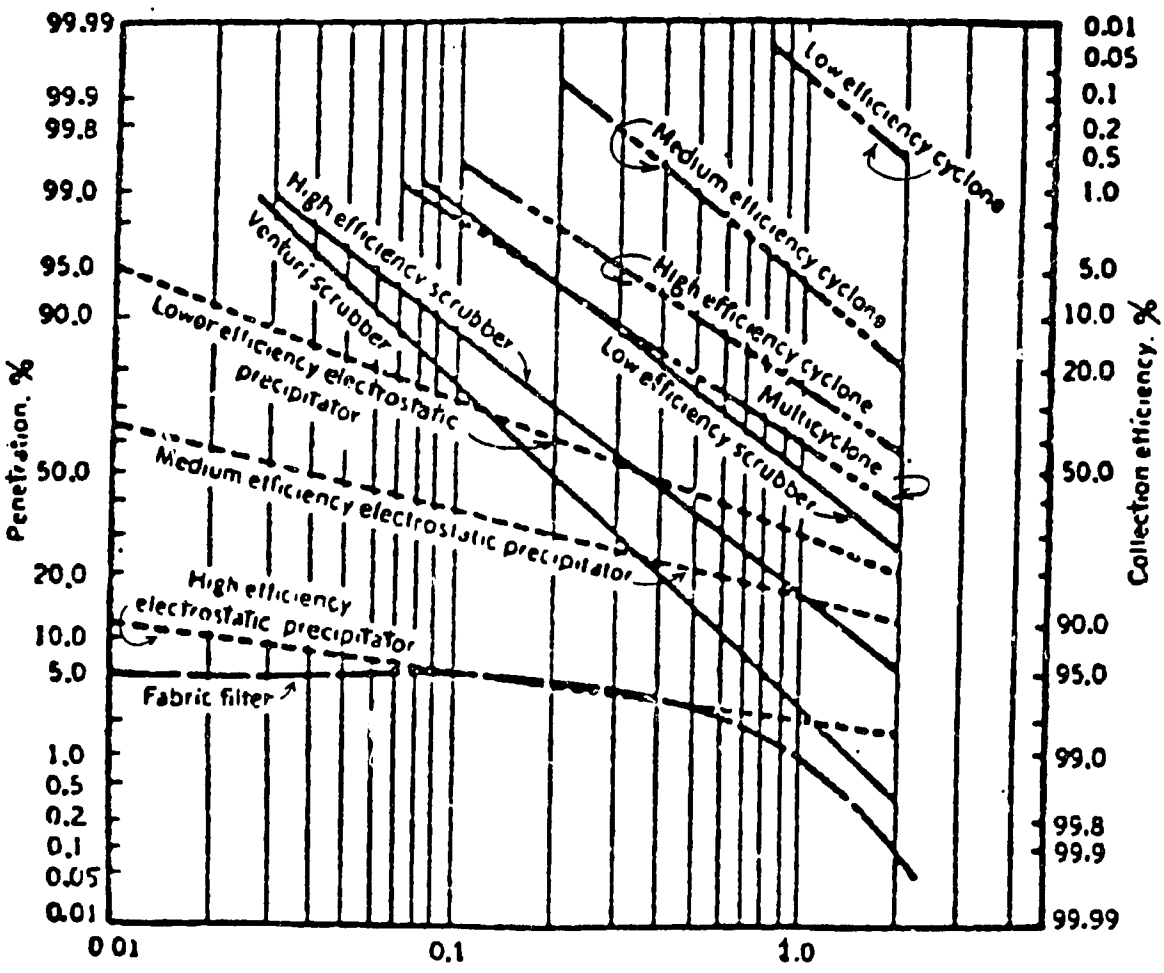
The blast furnace operations included a dust catcher and wet scrubber system for cleaning the furnace top gas. Cleaning of the top gas is essential to the furnace operation since the gas is a source of energy and is fired at the three stoves.

During the three-day visit to the plant, it was not possible to fully evaluate the effectiveness of the installed air pollution control equipment within the plant. The most certain observation was the lack of pollution control equipment at the two LD furnaces and the electric arc furnace. The plume from their respective stacks is visible for many kilometers from the plant. These furnaces should receive first priority for any expenditures for pollution control equipment.

The selection of control equipment for any particulate source such as the furnaces, is in the final analysis based on the system which meets the required performance at the lowest capital and operating costs. The physical parameters affecting the selection criteria include the particulate size and characteristics, the gas characteristics and the by-products of the operation, such as contaminated water or dust.

The particulate characteristics include particle size distribution, concentration, bulk density, moisture content, electrical resistivity and flammability. Gas characteristics include average and extreme flow rates, pressure, temperature, moisture content and reactivity. The method of disposal or treatment of the by-products is also a consideration. Space availability is also frequently a major factor.

The single most important physical parameter in the control device selection is particle size. For instance, the particle size distribution of the particulate in LD furnace off-gas is reported as 85-90 percent by weight less than one micron and 10-15 percent less than one-half micron. Reference to Figure 1 shows, <u>based on this particle size distribution</u>, that mechanical collectors such as multiclones are ineffective. The only control devices which would be applicable are the electrostatic precipitator, venturi scrubber or fabric filter. A fabric filter, however, cannot be used for the LD furnace application due to the high (2760°C) hood combustion zone temperature. The available technology for the LD furnaces, therefore, is an electrostatic precipitator or venturi scrubber.



FINE PARTICULATE
FRACTIONAL EFFICIENCY

FIGURE 1

The electric arc furnace particulate emission is similar in size to the LD furnace. The technology available for control is the same as the LD furnace except a baghouse can be used due to the lower gas temperature.

The lime kiln was not visited and may not have been operating at the time.

The following sections will review those areas where dust collection and suppression systems are typically installed in the steel plants of industrialized nations. In some cases, alternative ideas are suggested. The final decision to install dust collection equipment and the type of equipment can only be arrived at after a detailed engineering and cost study for the particular emission source.

3.2.2 LD Furnaces - Particulate Emission

The ELFOULADH steel plant has two 20 metric tonne capacity LD furnaces producing an annual total of 140,000 metric tonne of molten steel (see Figure 2). The furnace shop has no equipment to capture the particulate from the off-gases during the furnace blow.

The off-gases are directed into an open, membrane type, water-cooled hood. The fume and particulate ascend up the stack and discharge into the atmosphere at approximately 34.75 meters above yard elevation.

Fumes generated during reladling of the hot metal at the mixer and while charging the hot metal into the LD vessel and while tapping the molten steel from the vessel, ascend through the building structure and discharge to atmosphere through the building ventilators.

A rough estimate of the weight of particulate which will be discharged during the oxygen blow is 1-1/2 to 2 percent of the metallic charge. For an annual production of 140,000 metric tonnes per year and a yield of 87 percent, the total metallic charge is 161,000 metric tonnes. Therefore, the weight of particulate which may be discharged to the atmosphere is 2,400 to 3,200 metric tonnes per year.

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FIGURE 2

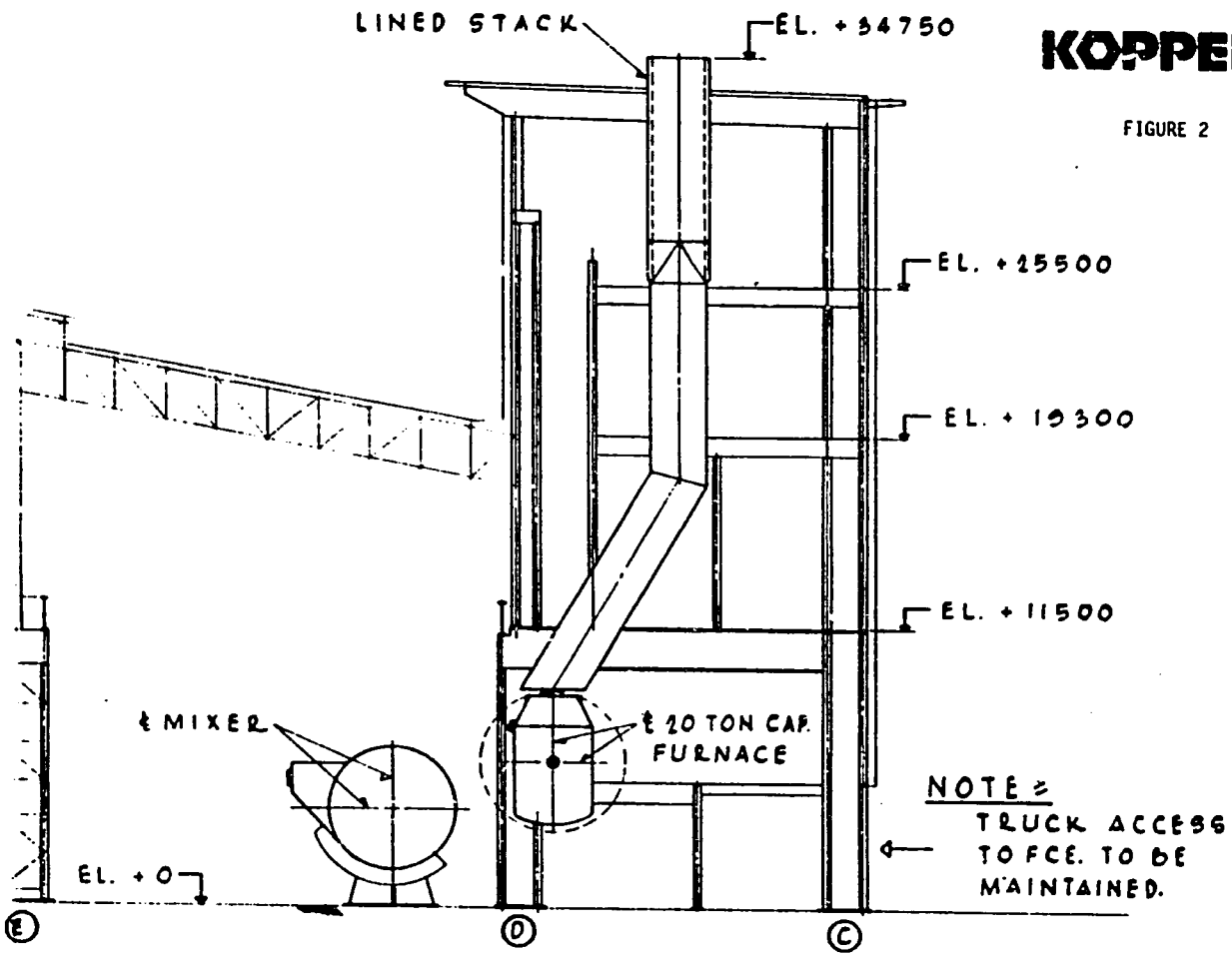


FIGURE 2

12 24

The particulate is composed essentially of Fe_2O_3 with small amounts of FeO and MnO_3 and traces of the oxides of silicon, calcium, aluminum and phosphorus. The particle size is typically very fine with about 85 percent by weight being less than one micron and 15 percent is less than 0.5 microns.

The dust loading in the waste gases at the LD furnaces will vary widely during the oxygen blowing period (15 minutes) and will reach a peak after the CO evolution begins.

Because of its fineness, the dust may be scattered over a wide area. At the stack discharge, elevation 34.75 meters, the fume and particulate are dispersed, at the vagaries of the prevailing winds, across the surrounding country side, Lake Bizerte and, on occasion, the nearby city of Menzel Bourguiba.

3.2.3 LD Furnaces - Particulate Control Technology

Particulate emissions from the LD furnace shop can be divided into two broad categories. First and foremost are those which are generated during the oxygen blow--a period of about 15 minutes for each heat. Secondary emissions are those generated while reladling from the mixer ladle to the charging ladle, while charging from the ladle into the LD furnace, and when tapping the furnace into the steel ladle.

At present, the primary emissions are directed into the water-cooled hood and ascend through the stack and discharge to atmosphere. The optimum method for collecting the particulate can only be determined by a detailed engineering study. This report can only suggest guidelines which would be considered in the study.

One of the initial determinations should be the adequacy of the existing hood for collection of the fume and particulate. A few minutes of observation by the survey team seem to indicate that the hood was of adequate size. However, this needs to be reviewed. The operators may

provide some input, particularly if they have observed fumes ascending through the shop in addition to the stack. It is possible the hood may need to be enlarged or it may need to be brought closer to the vessel mouth to restrict the infiltration of air to that needed for combustion. It is probable that the hood arrangement at this plant would be an open type. Steam and water sprays would be installed in the hood to quench the hot (1650°C) gases.

One method which has been used to contain the fumes to minimize their dispersion to the upper levels of the furnace shop is to provide an enclosure around the furnace between the operating and service floors. The enclosure is arranged to direct the fumes into the hood. Figures 3 and 4 illustrate a three-sided furnace enclosure. The open side was necessary because a charging machine on the operating floor was used to charge the scrap. A similar three-sided enclosure would be applicable to the ELFOULADH furnaces which are generally located in the charging crane and building column lines. The mouth of the vessel rotates into the charging aisle so that side must remain open. These furnaces are charged and tapped from the same side while the slag is drained from the opposite side.

The enclosure consists of a steel framework with loosely fitted hematite panels to resist warping by the heat. Rolling or man doors can be provided on the slagging side of the furnace. The roof of the enclosure would be arranged to direct the fumes into the hood.

3.2.3.2 Venturi Scrubber

High energy venturi scrubbers can be very effective in collecting the dust with efficiencies in excess of 99%. The scrubber itself requires a minimum of space and can normally be located near the furnaces, thus keeping the capital cost low. However, entrainment separators, exhaust fan, and treatment of the scrubber effluent requires additional space for the flocculator-clarifier, vacuum filter and pumps. These units can, if necessary, be located remote from the furnace area.

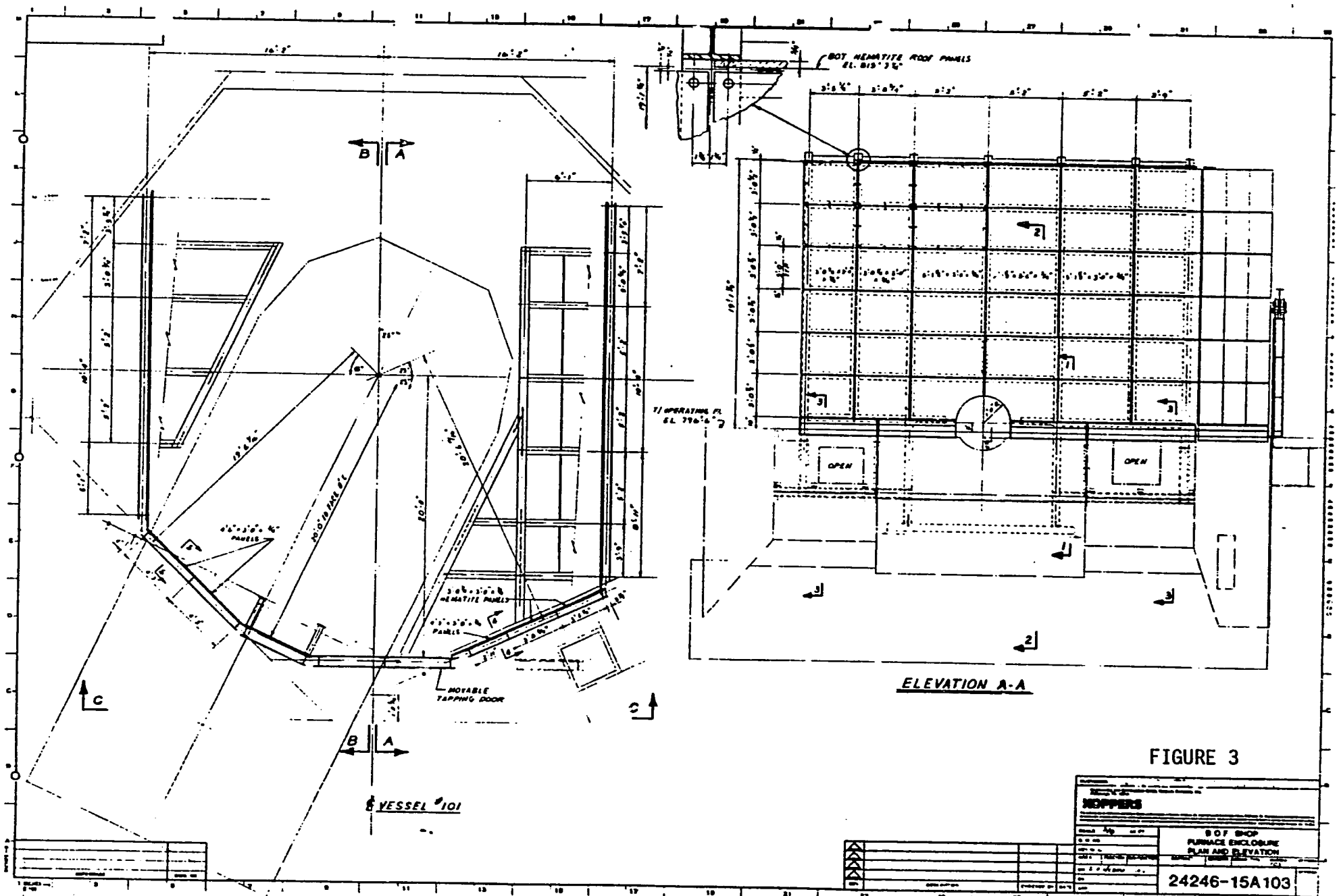

BOT. HEMATITE ROOF PANELS
EL. 815'-3 1/2"
T/ OPERATING FL.
EL. 796'-6"
OPEN
OPEN
HEMATITE PANELS
PANELS
MOVABLE TAPPING DOOR
℄ VESSEL #101
ELEVATION A-A
NOPPERS
BOF SHOP
FURNACE ENCLOSURE
PLAN AND ELEVATION
24246-15A103

FIGURE 3

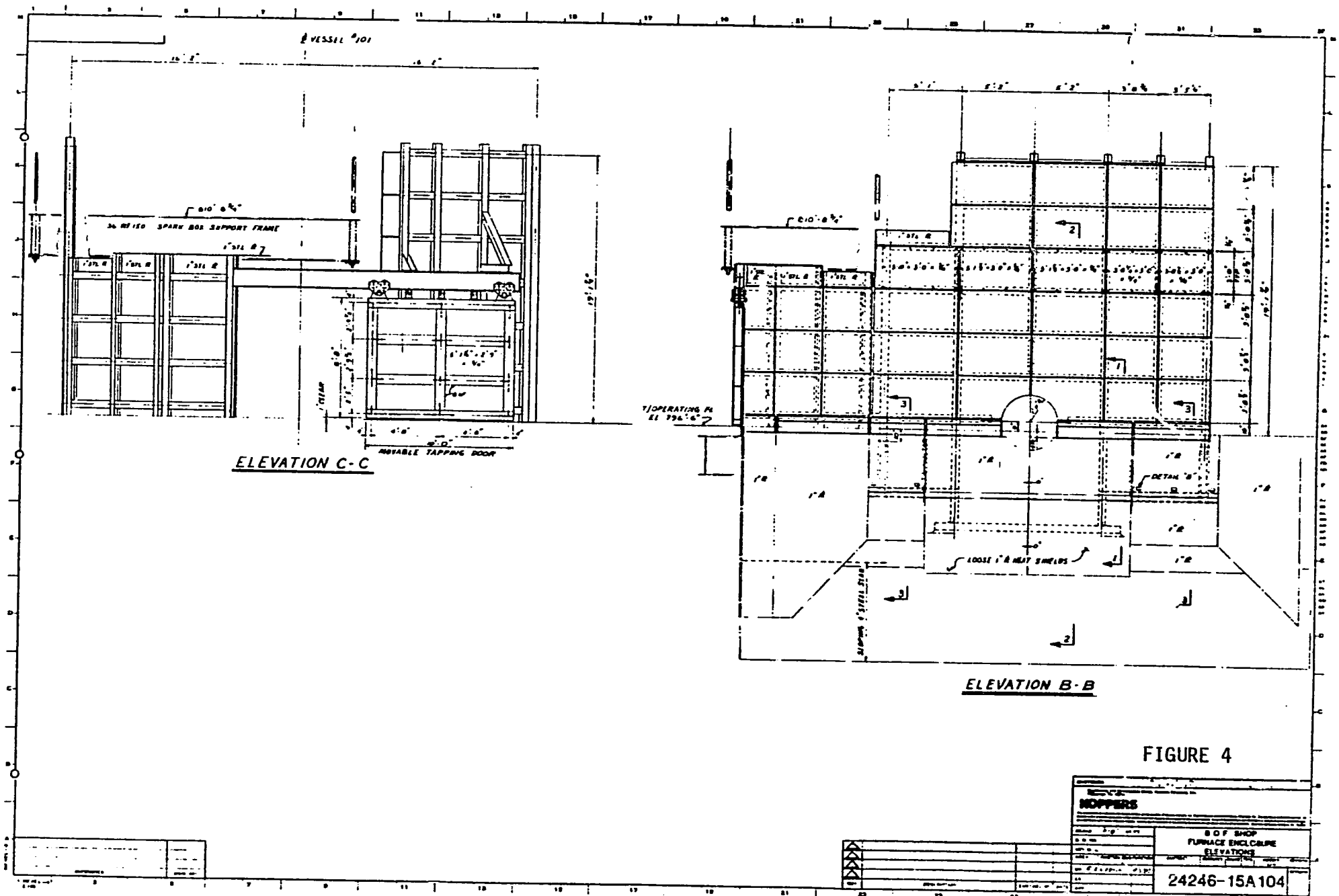

VESSEL #101
SPARK BOX SUPPORT FRAME
MOVABLE TAPPING DOOR
ELEVATION C-C
DETAIL "B"
LOOSE 1" R HEAT SHIELDS
ELEVATION B-B
HOPPERS
BOF SHOP
FURNACE ENCLOSURE
ELEVATIONS
24246-15A104

FIGURE 4

Scrubber and effluent treatment equipment are generally low maintenance items but high energy consumers. The wetted dust from the vacuum filter is easily handled for transport to a landfill or to the sinter plant raw materials bins. This dust may be objectionable if it contains zinc since this metal adversely affects the operation of the blast furnace. If the scrap charge contains large amounts of in-plant scrap from the galvanizing operations, then the dust should be dumped into a properly designed and operated landfill. The scrubber frequently has a steam plume discharging from the stack and under certain circumstances, can create a negative reaction from the general public which may consider the plume as pollution.

3.2.3.3 Electrostatic Precipitators

Electrostatic precipitators provide high collection efficiencies at low power consumption. They have greater space requirements and need more maintenance than scrubbers. The dust can be removed either wet or dry, however, the wet precipitator will require a clarifier to separate the dust from the water. Dry dust, on the other hand, can be difficult to handle and this is particularly true for the fine dusts from the LD furnace. Capital costs for precipitators are usually higher than for the scrubber, but an engineering and economic study must be made for an accurate judgement.

If electrostatic precipitators are selected, it is important that sufficient excess air is drafted through the hood to burn the CO to CO_2, otherwise the potential for an explosion in the precipitator exists. It is also important not to draft an excessive amount of air through the furnace hood since this will increase the size requirement for the precipitator.

Availability of a precipitator is nearly 100 percent. Failure of discharge wires and plates can usually be isolated so that the balance of the system can operate. Dampers can be provided to block off sections for repair while gas cleaning continues at a reduced rate.

3.2.4 LD Furnace Control Recommendation

The technologies available for control of the LD furnaces, as previously described are an electrostatic precipitator or a high energy venturi scrubber. Many LD type furnaces in the United States are controlled by electrostatic precipitators.

It is recommended that ELFOULADH consider installation of a precipitator on the LD furnaces rather than a venturi scrubber. It is obvious that the recommendation is tentative since a detailed engineering and economic study would be required before a final decision could be made.

This recommendation is based on generalized cost data since there was insufficient time and information available for a detailed analysis.

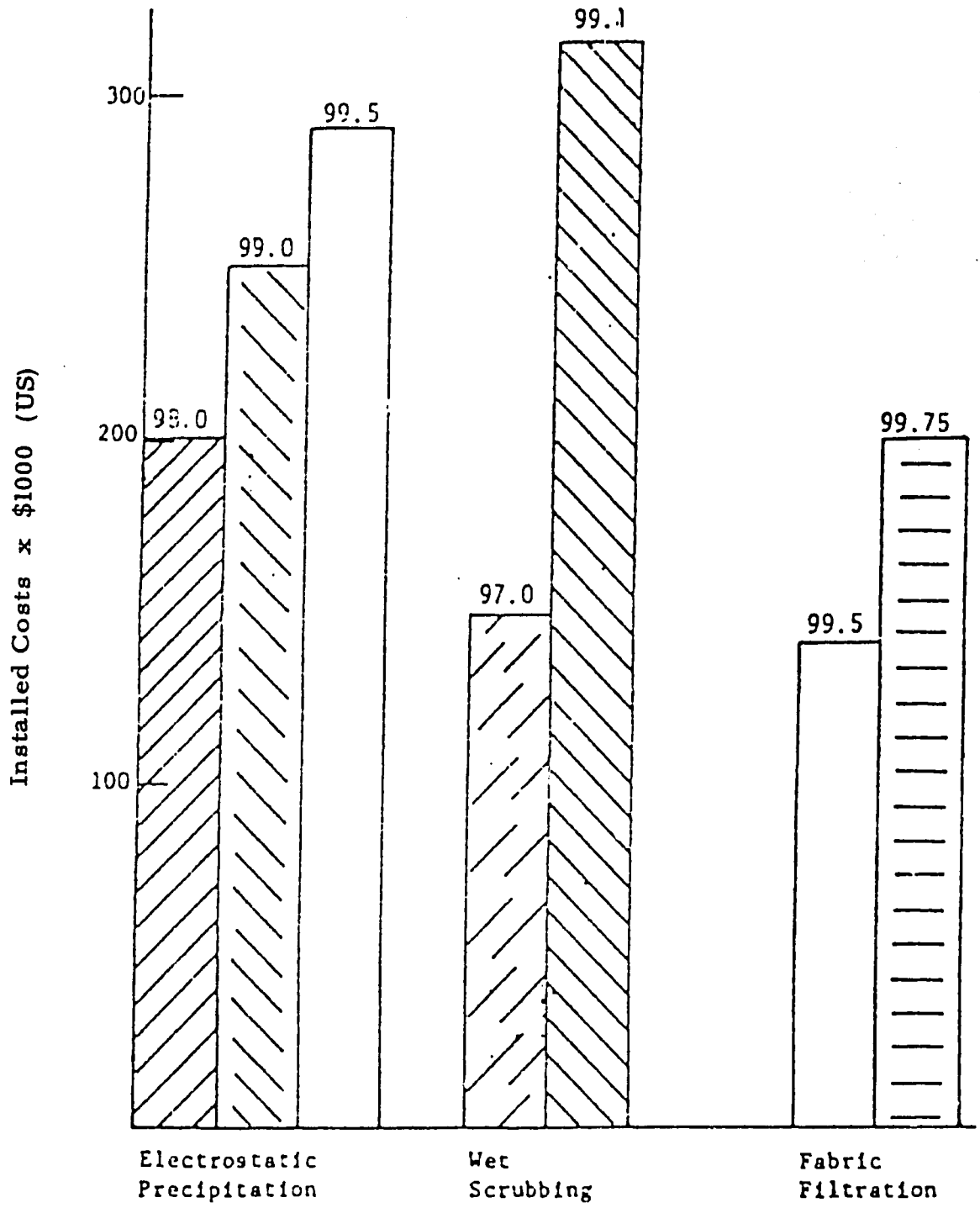
Figures 5, 6, and 7 present comparative USA costs (as of 1976) for precipitators, venturi scrubbers and baghouses, versus removal efficiencies. While this data if generalized and the costs somewhat dated, the relative differences are believed to be valid.

Note that for the two control options considered here, the electrostatic precipitator is the best selection in the efficiency range covered. The venturi scrubber has the highest installation and operating costs.

The cost of a precipitator (equipment only) for ELFOULADH's LD furnaces is estimated to be in the range of $500,000-$750,000 USA.

There are other alternatives which could be evaluated when the detailed study is initiated. One option is that it may be feasible to use one large precipitator to handle the waste gases from both the LD furnaces and the electric arc furnace. This approach would reduce the overall cost.

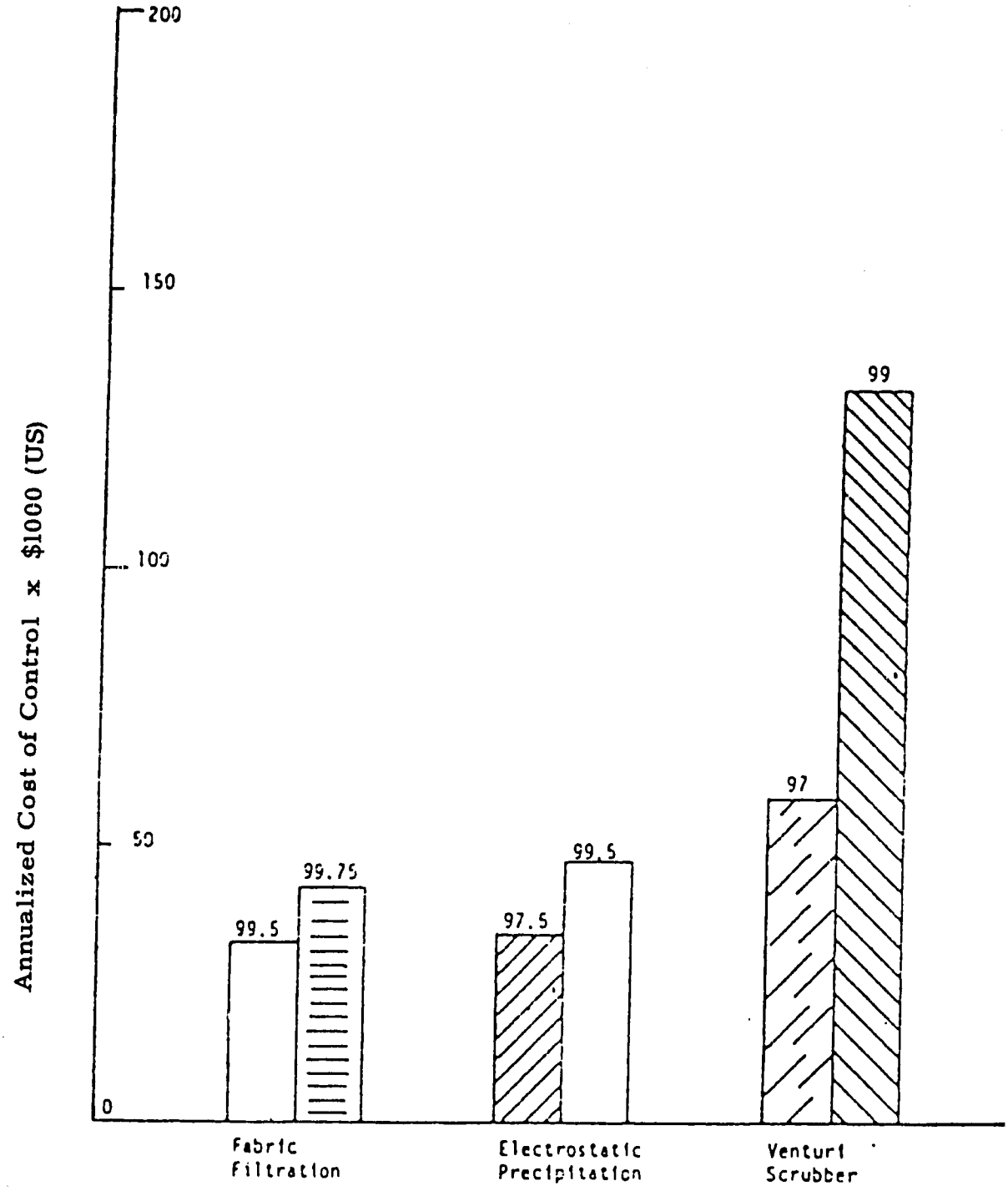
A second option, which certainly would not be considered in the USA and may not be technically feasible, would be the use of a mechanical



Installed Cost Comparisons at Varying Efficiencies

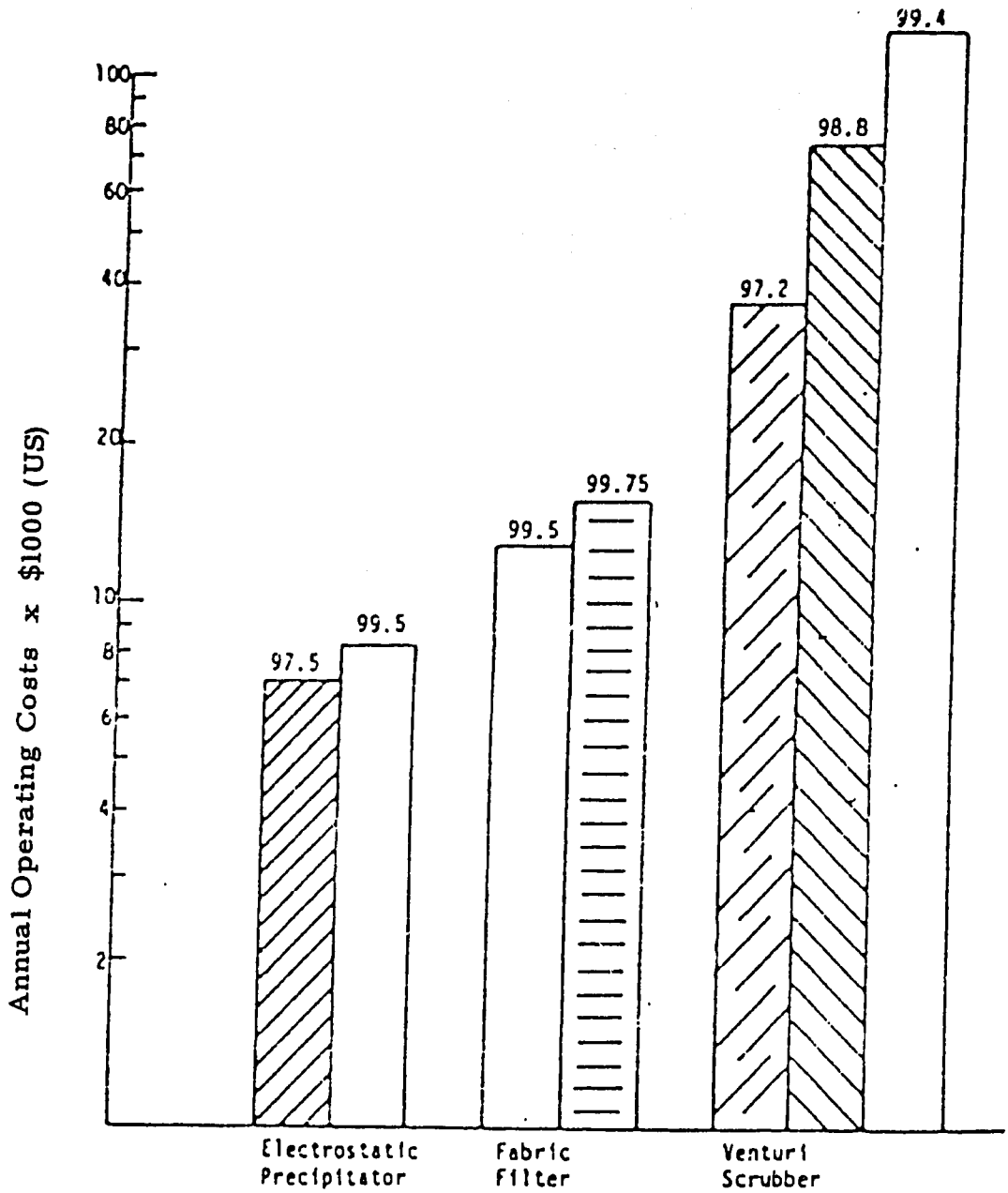
FIGURE 5

31.



Annualized Cost for Varying Efficiencies

FIGURE 6



Operating Cost Comparisons for Varying Efficiencies

FIGURE 7

collector. Since this control would cost much less than a precipitator, it may be worth investigating.

Consider that in the USA, regulations require the best available technology for furnace emisions control. This means a device with particulate removal efficiency of 99+% and an exhaust vent gas stream essentially invisible. If ELFOULADH would for an interim period accept a removal efficiency of perhaps 70 percent and a visible stack plume, a mechanical collector might be adequate. It should be noted that this device does not remove the fine particulate which are a greater impact on health than the larger particles. The cost, of course, would be about one-tenth of a precipitator cost.

The feasibility of the above option depends on the particle size distribution from an uncontrolled furnace. Data presented in this report indicates that 85-90 percent, by weight, of the furnace particulate is less than one micron. There is, however, other particle size distribution data available in the literature which shows 25% of particulate less than one micron. The distribution is such that a multiclone could possibly remove 70 percent of the particulate. It has not been possible to establish the validity of either set of data.

In order to evaluate this option, it would require establishing a reliable particle size distribution from an uncontrolled operation, perhaps by actual source test.

There is no doubt that the best solution to the LD furnaces emission would be a precipitator, if the capital were available. Even if a mechanical collector could achieve 70 percent efficiency, additional control would be required in the future, as the government's environmental program progresses so that the final cost would appreciably exceed an initial precipitator installation.

3.2.5 LD Furnace - Secondary Emissions

Secondary emissions are those which are generated while pouring the hot metal in and out of the mixer ladle and while charging and tapping the LD furnaces. The intensity of the emissions during these operations is not nearly so great as during the oxygen blow, nevertheless the emissions can be considerable. In one USA shop, it has been estimated that 0.0776 Kg per metric ton of hot metal is generated when transferring hot metal between ladles and the furnace.

These emissions consist of two components, kish which is primarily graphite platelets, and fume which is finely powdered iron oxide. By weight, about 80 percent is kish and 20 percent is fume. Typically, the particle size is 99 percent less than 3 microns and 70 percent less than 1 micron.

The kish and fume are known to create problems with cranes, causing excessive wear in bearings, gears, drums, rails and fouling electric circuitry. Accumulations of this particulate can make walking in the area difficult and dangerous.

These secondary emissions are presently dispersed through the shop atmosphere and either settle on the equipment, building steel and floor areas, or ascend to the roof and discharge to atmosphere through the roof ventilators. These emissions have a greater effect on the shop operations than they do on the areas and populace adjoining the steel plant.

Increasingly, steel plants in the industrialized countries are capturing these particulates to meet the requirements of the local clean air regulations. Where hot metal is poured, hoods are installed over the pouring or receiving vessel, whichever is more convenient. The fume and kish are then ducted typically to a baghouse. The low temperatures and small particle size are particularly adaptable to bag filter collection. Draft is provided by a fan. A stack with a relief valve at the top is provided to release the fume to atmosphere during emergencies.

During charging and tapping of the LD furnaces, the furnace is rotated out from under the hood and the fumes generated during these operations ascend through the building structure and out the roof ventilators to the atmosphere. A hood could possibly be installed over the vessel mouth when in the slag dumping position. The fumes could be ducted to the new dust collection system at the furnace. It does not appear possible to collect the fumes during the furnace charging or tapping period since the vessel mouth rotates well out into the charging aisle and this would create an interference with the charging crane.

There can be a reduction in the secondary emissions if the hot metal and molten steel are poured slowly. However, this is not a very satisfactory solution to the emissions problem; hooding and baghouses provide a more effective means for fugitive emissions reduction.

3.2.6 Electric Arc Furnace - Particulate Emission

The single 15 tonne capacity electric arc furnace is equipped with a fourth hole in the furnace roof (see Figure 8). The fumes generated during melting and refining are aspirated from the fourth hole and flow via ductwork to an underground flue which crosses the furnace aisle. The fume is then vented through a stack at the building column row. The uncontrolled particulate is discharged to atmosphere at an elevation of 36 meters. In addition to this "process particulate," fugitive particulate is generated during the charging and tapping operations.

The fume from the arc furnace is similar to that from the LD furnace in that it contains the oxides of iron and is in the submicron range. The intensity of the fume is greatly affected by the content of oil in the scrap and by the amount of oxygen used during scrap meltdown and refining. At present, oxygen is used only during the refining period and little or no oil is present in the scrap. The size of the furnace dust collection equipment will be increased if future plans call for oxygen use during the meltdown period.

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FIGURE 8

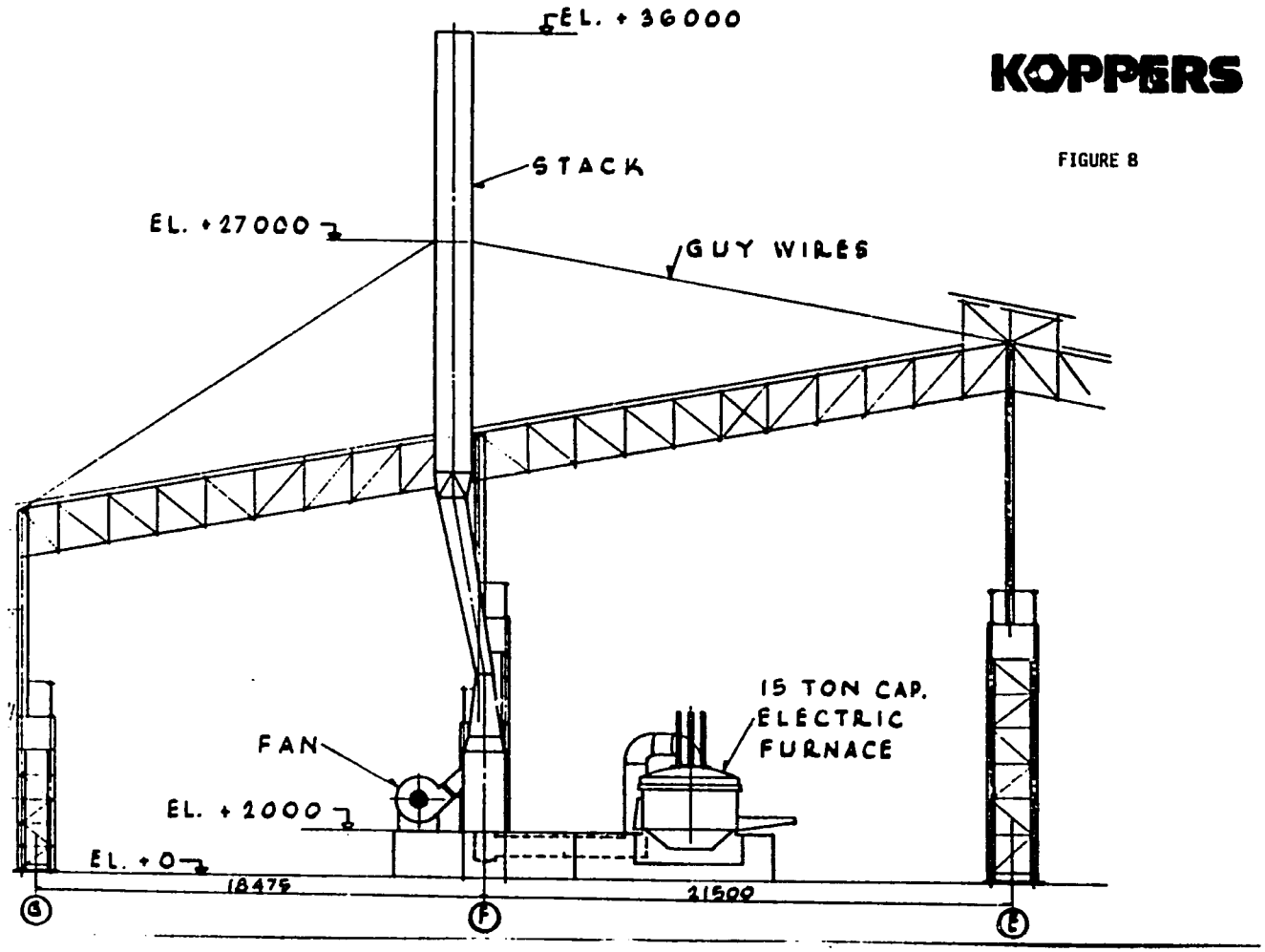


FIGURE 8

The waste gas volume passing through the fourth hole is in the range of 1,200 cubic meters per tonne of steel and the dust loading will range between 2.5 to 8 kg per tonne of steel.

3.2.7 Electric Arc Furnace Control Technology

Particulate laden fumes are generated at the electric furnace during the charging, meltdown and tapping phases of the operation. Current regulations in the USA require that the particulates generated during meltdown and the fugitive particulates emitted during charging and tapping be controlled.

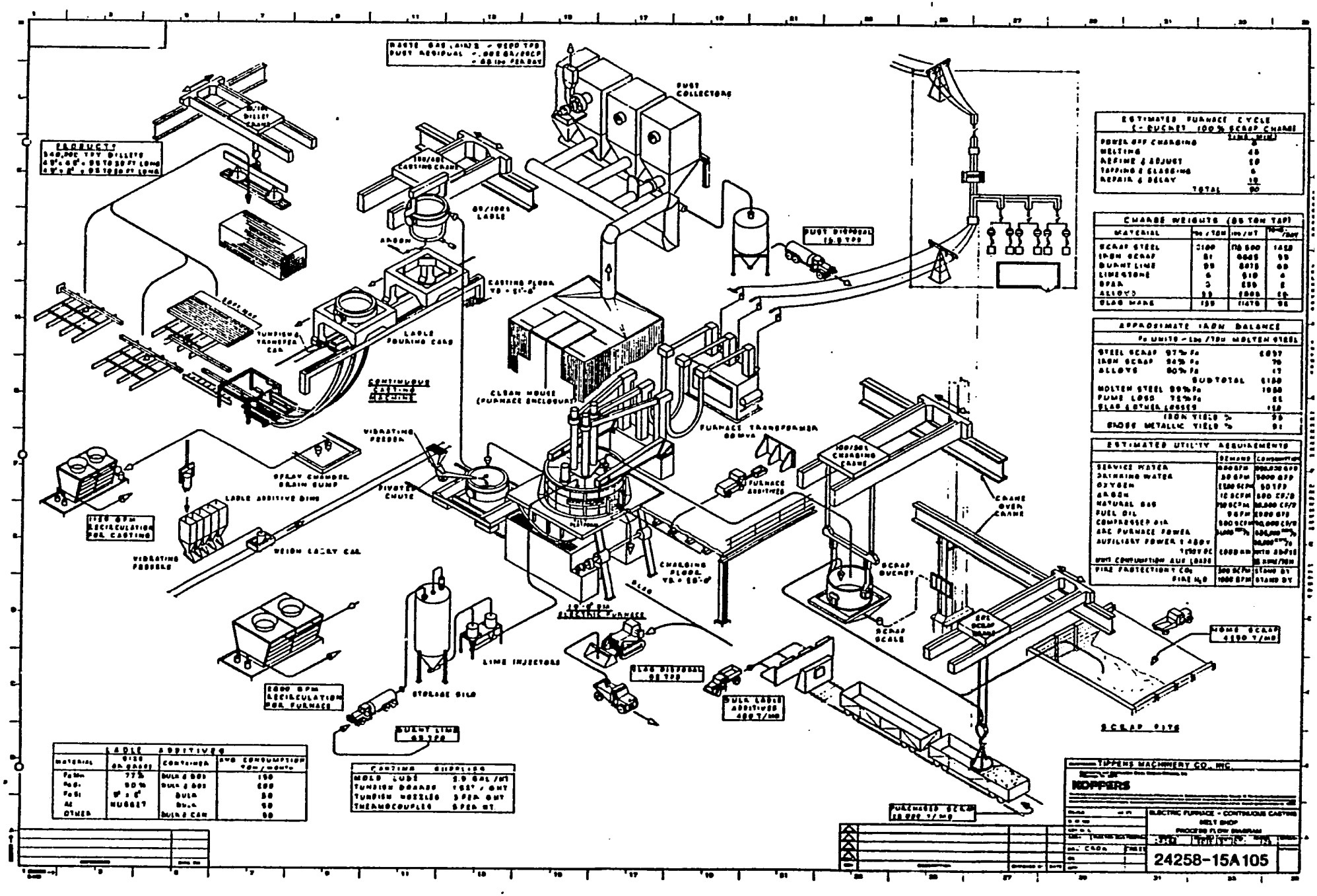
Various methods are being used to implement the current requirements as follows:

3.2.7.1 Total Enclosure

The most effective method for capturing both the process and fugitive particulate is to enclose the furnace and tapping area as shown on Dwg. 24258-15A105 and Figures CH-1 through 4. This system has the additional benefit of muffling the noise of meltdown. Doors are arranged in the enclosure to admit the scrap charging bucket, a mobile charger, and personnel. The fourth hole in the furnace roof is filled with a short, upright chimney rather than a direct evacuation elbow. Fumes emitted from the fourth hole, electrode openings and other apertures in the furnace, as well as tapping fumes are contained by the enclosure and evacuated at a controlled rate through a baghouse. High ratio jet pulse filter modules are used to collect the dust which is then pneumatically transferred to a dust bin. The average particulate concentration in the vent gas stream is 0.07 gr/Nm^3 (dry).

3.2.7.2 Canopy Hood & Direct Evacuation

Another, though less effective solution to capture the fugitive particulate is to install a canopy hood over the furnace. The meltdown emissions are


DUST COLLECTORS
DUST DISPOSAL
BILLET CRANE
PRODUCTS
100/50t CASTING CRANE
50/100t LADLE
ARGON
CASTING FLOOR
LADLE POURING CARS
TUNDISH TRANSFER CAR
CONTINUOUS CASTING MACHINE
CLEAN HOUSE (FURNACE ENCLOSURE)
FURNACE TRANSFORMER
VIBRATING FEEDER
SPRAY CHAMBER DRAIN SUMP
LADLE ADDITIVE BINS
DIVERTER CHUTE
FURNACE ADDITIVES
100/50t CHARGING CRANE
CRANE OVER CRANE
VIBRATING FEEDERS
WEIGH CARRY CAR
CHARGING FLOOR
SLAG
SCRAP BUCKET
SCRAP SCALE
SCRAP PITS
LIME INJECTORS
STORAGE SILO
SLAG DISPOSAL
BULK LADLE ADDITIVES
SLURRY LIME
ESTIMATED FURNACE CYCLE
CHARGE WEIGHTS
APPROXIMATE IRON BALANCE
ESTIMATED UTILITY REQUIREMENTS
LADLE ADDITIVES
CASTING SUPPLIES
TIPPENS MACHINERY CO. INC.
KOPPERS
ELECTRIC FURNACE - CONTINUOUS CASTING
MELT SHOP
PROCESS FLOW DIAGRAM
24258-15A105

Z 39

BIRD'S-EYE VIEW CLEAN HOUSE SYSTEM

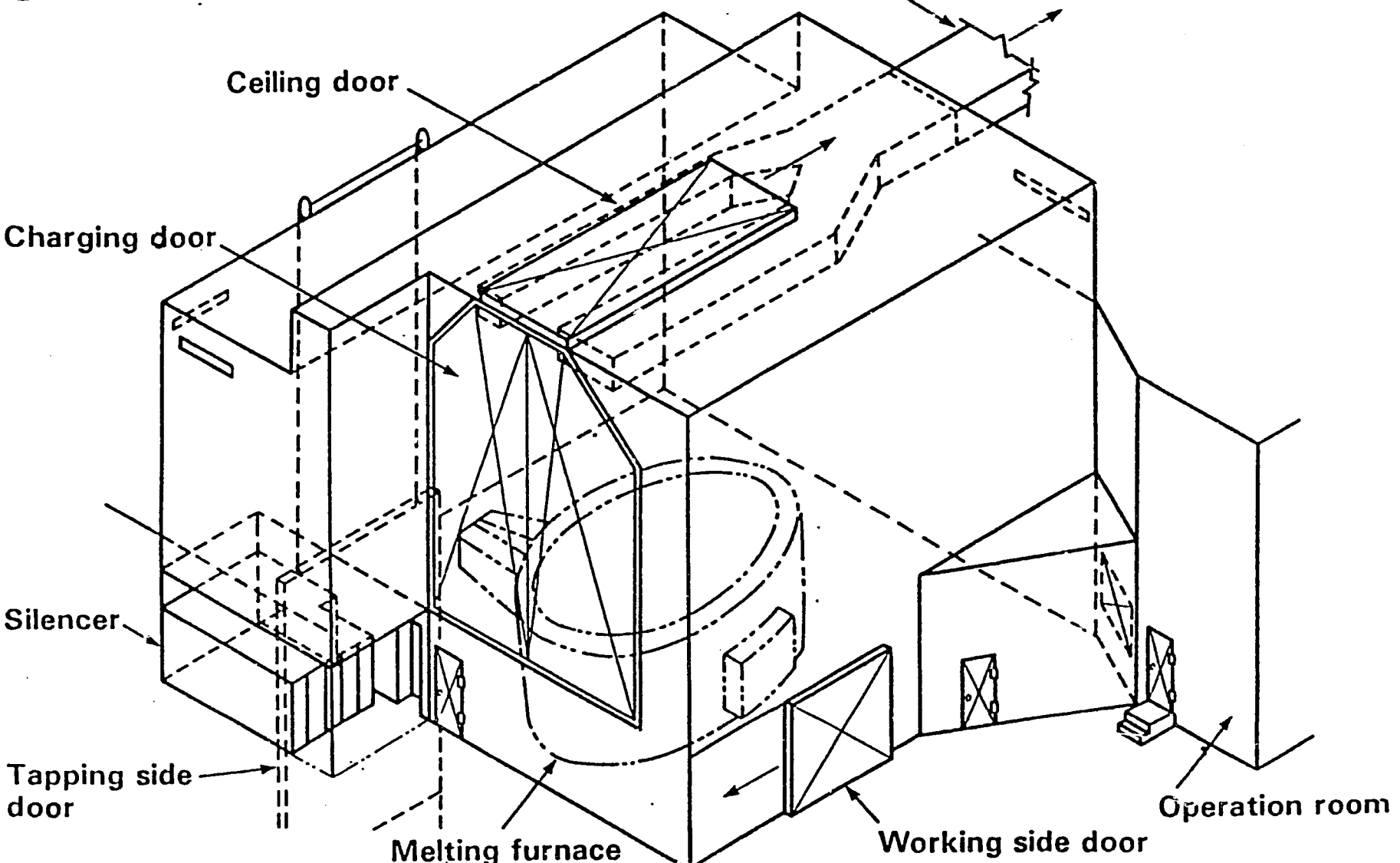


Fig. CH-1

FIGURE CH - 1

GENERAL ARRANGEMENT (PLAN)
CLEAN HOUSE SYSTEM

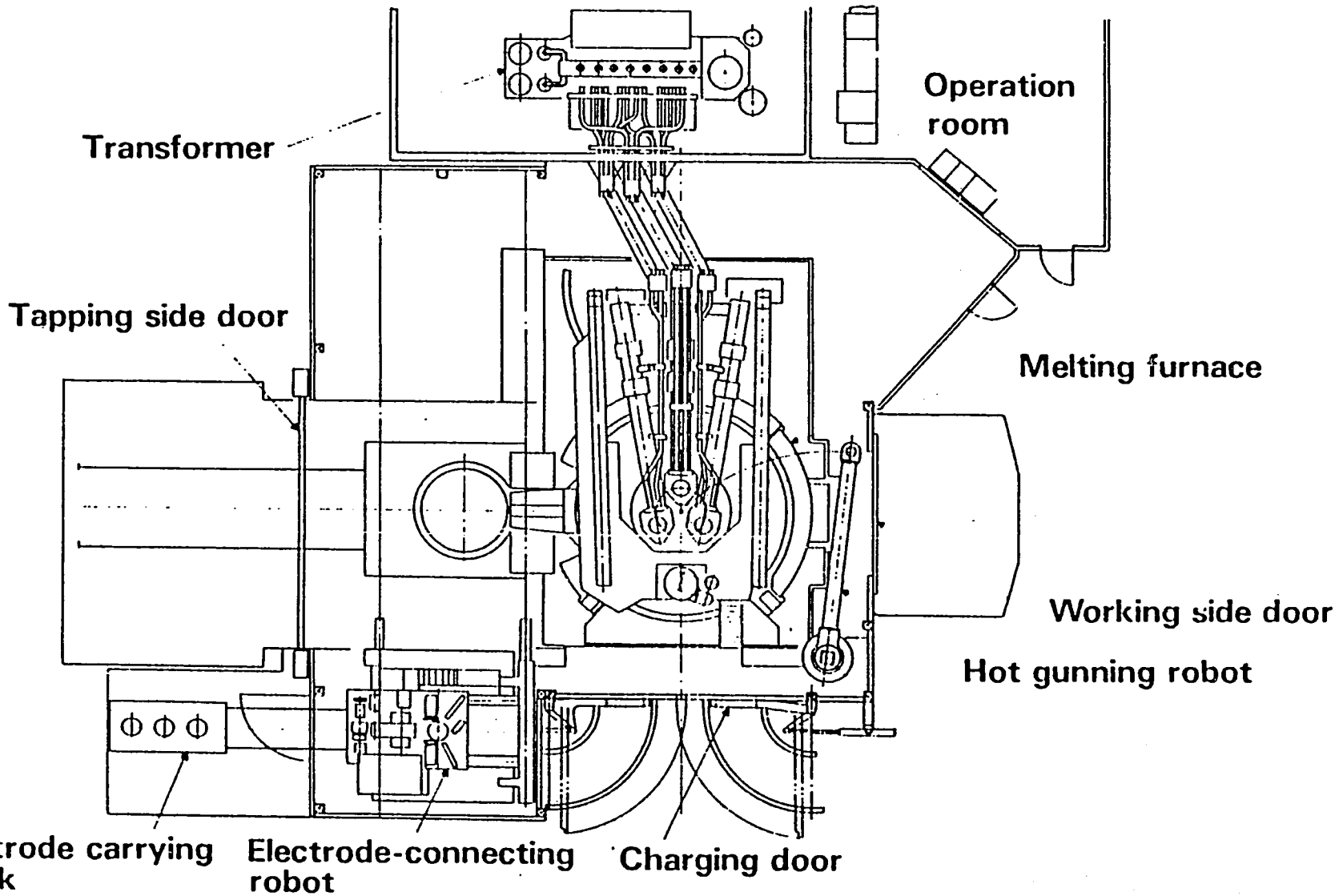


FIGURE CH - 2

Fig. CH-2

GENERAL ARRANGEMENT (SIDE VIEW)
CLEAN HOUSE SYSTEM

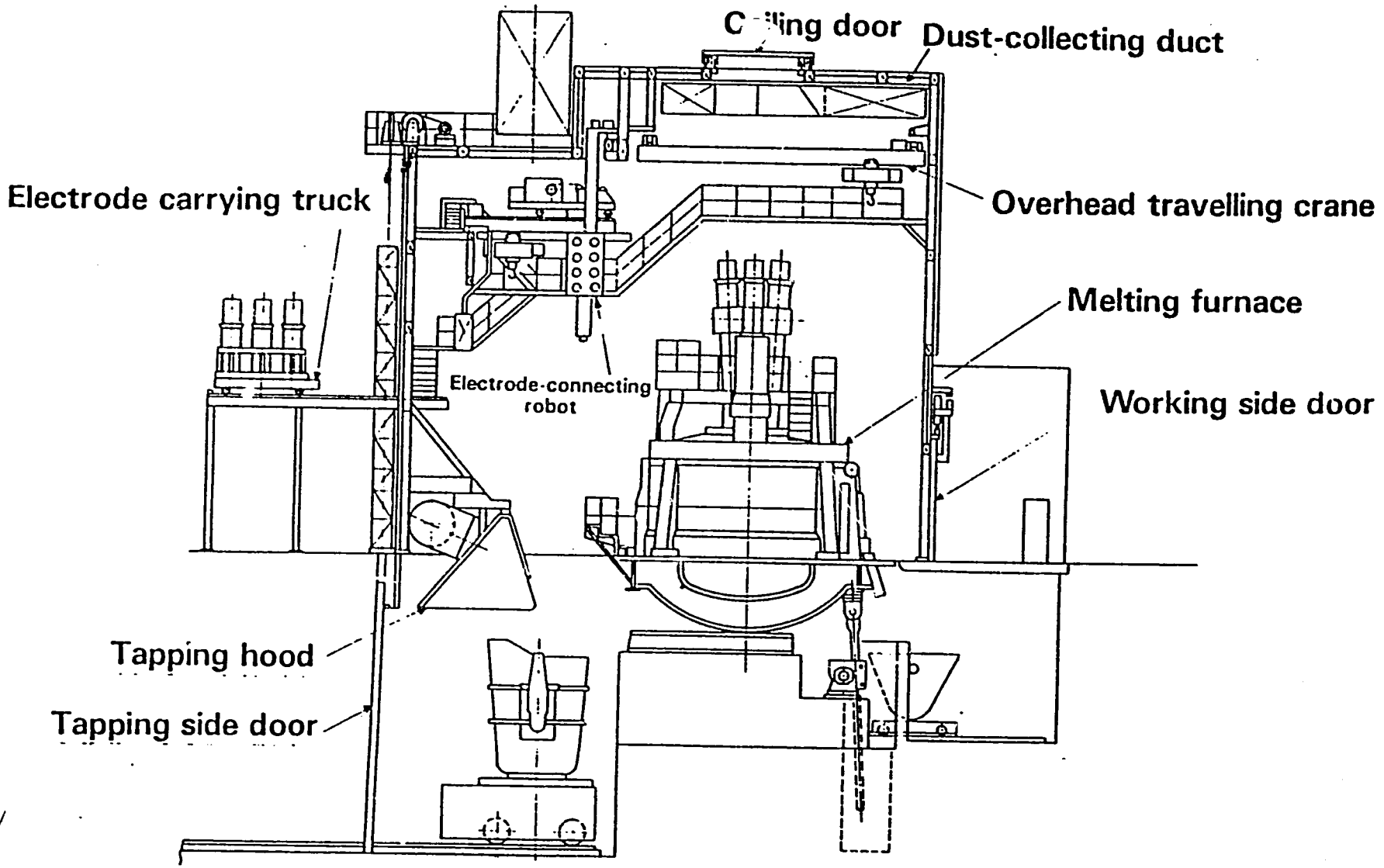


FIGURE CH - 3

Charging door side of Clean House

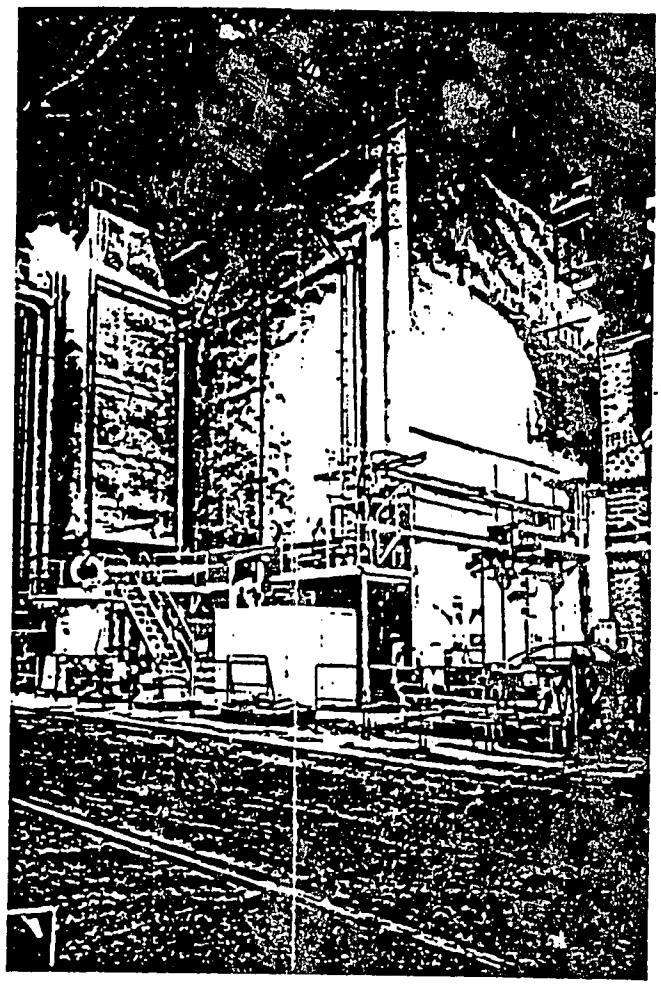


FIGURE CH - 4

collected by direct evacuation from the fourth hole in the furnace roof. A typical arrangement is shown schematically in drawing 24073-79-BB. Much of the particulate which escapes capture by the direct evacuation system will be picked up by the canopy hood system. This will include particulate which escapes through the electrode holes, and that which is generated when charging and tapping the furnace.

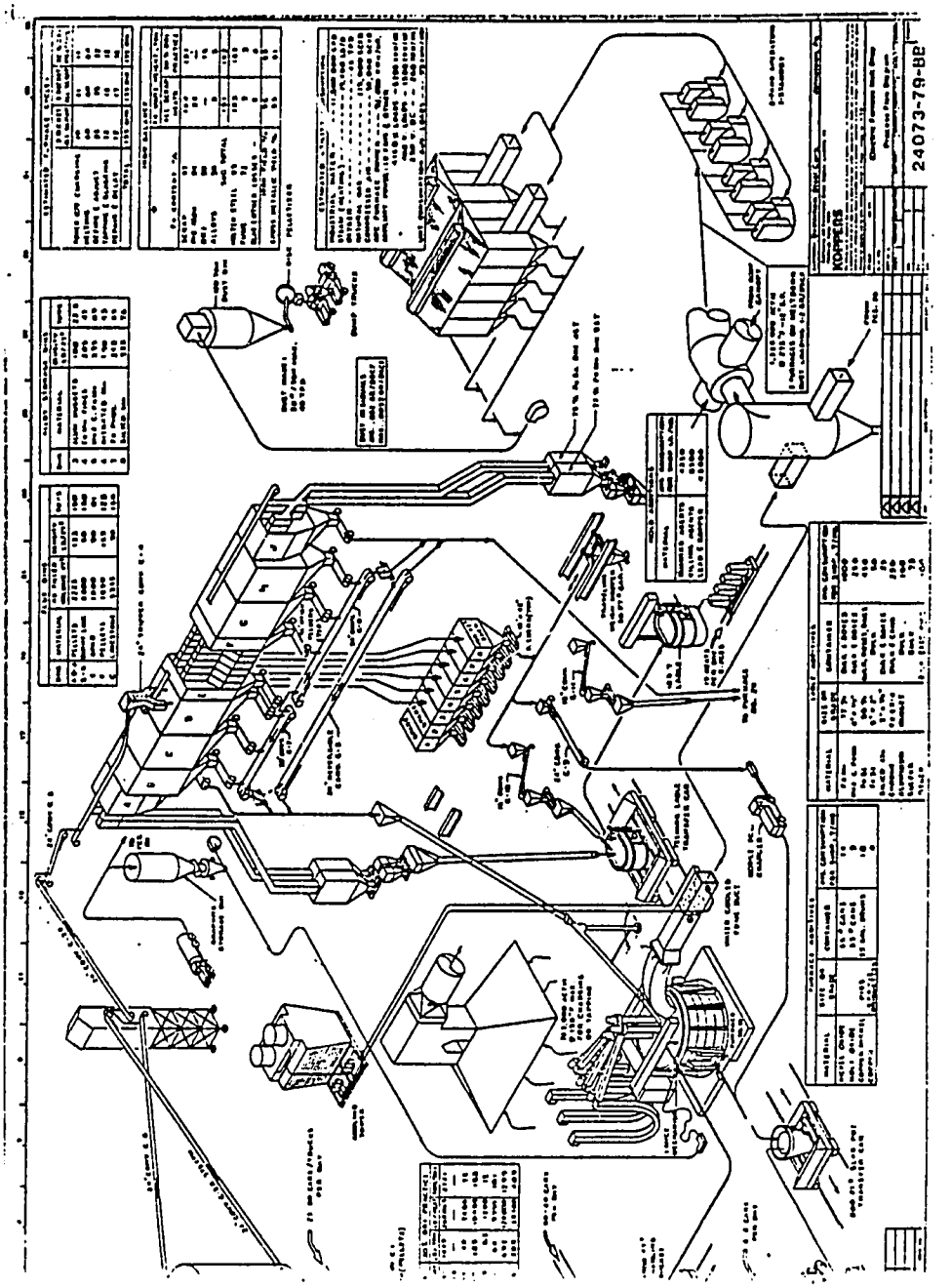
Hot air currents from the furnace operation carry the fugitive particulate into the canopy hood where it is then ducted to a baghouse for removal of the particulate. This arrangement does not muffle the noise, requires a larger baghouse and evacuation fans than total enclosure because a greater proportion of ambient air is drawn into the system. These factors result in higher capital and operating costs. Figure CH-5 illustrates the comparative costs between the clean house enclosure and combination canopy hood with direct evacuation dust collectors.

The above solutions for capture of both fugitive and process particulate from the electric arc furnace are best implemented during the original design and construction of the facility. To add a new enclosure, hoods, and ductwork to an existing installation may require substantial alterations and strengthening of existing structures.

3.2.7.3 Particulate Removal - Technology

The available technology for removal of particulate from electric arc furnace off-gases is basically the same as for the LD furnaces since the particle size distribution is very similar. In the case of the electric arc furnace, due to the lower exhaust temperature, a baghouse could be used as well as either a precipitator or venturi scrubber. The majority of USA installations utilize a baghouse. The discussion on precipitators and scrubbers covered under the LD Furnace would also apply to this source.

The baghouse depends on a filter media to remove dust from the gas stream and is capable of efficiencies for removal of fine particulate equal



ELECTRIC FURNACE MELT SHOP

PROCESS FLOW DIAGRAM

DRAWING 24073-79-BB

COMPARISON BETWEEN THE CONVENTIONAL SYSTEM AND CLEAN HOUSE SYSTEM

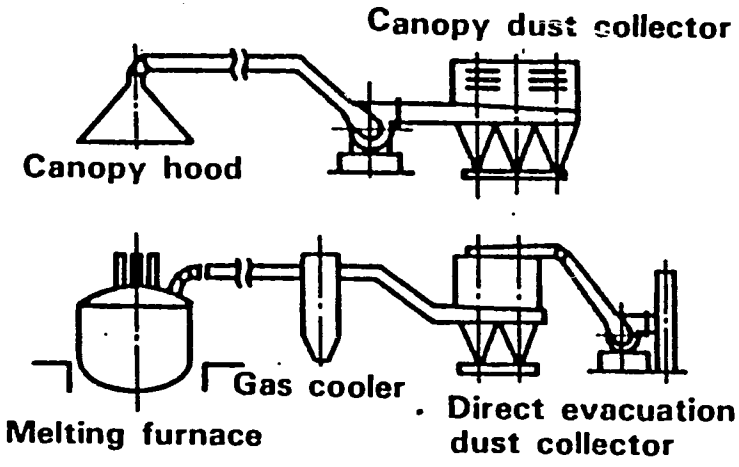
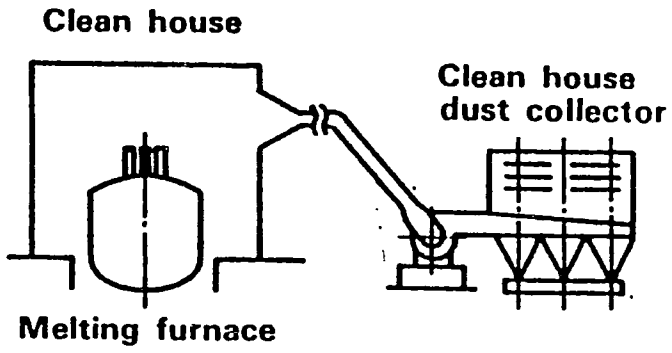
	Conventional system	Clean house system
Schematic illustration		
Capacity of dust collector	Canopy dust collector 15,000m³/min Direct evacuation dust collector 3,000m³/min	Clean house dust collector 5,000m³/min
Construction cost	Canopy dust collector + Direct evacuation dust collector + Gas cooler + α α : Canopy hood + modification of building $200+\alpha$	Clean house + dust collector 100
Running cost	150	100

FIGURE CH - 5

Fig. CH-5

to electrostatic precipitators and high energy venturi scrubbers. Baghouses are simple to operate and have essentially 100 percent availability.

3.2.8 Electric Arc Furnace - Control Recommendation

The technologies available for control of particulate from the electric arc furnace are an electrostatic precipitator, venturi scrubber, or a baghouse. A baghouse can be considered for use with the electric arc furnace, since the off-gas temperature is not nearly as high as in the case of the LD furnaces. The majority of the electric arc furnaces in the USA have baghouses for particulate control.

It is recommended that ELFOULADH consider installation of a baghouse on the electric arc furnace rather than a precipitator or venturi scrubber. As with the recommendation on the LD furnaces, this suggestion is tentative and further study is required before a firm decision is reached.

This tentative recommendation is based on the use of the generalized data shown in Figures 5, 6, and 7. From a review of this data, the baghouse has the lowest installation cost and is comparable to the precipitator with respect to operating and annualized costs. The venturi scrubber is not competitive.

The cost of a baghouse (equipment only) for the ELFOULADH electric arc furnace is in the range of $100,000-$200,000 USA.

The alternates discussed in Section 3.2.4 for the LD furnace are also applicable to the electric arc furnace control.

In sizing the dust collection system, consideration must be given to the future use of oxygen for increasing the meltdown rate. Use of oxygen increases the gas flow rate and, therefore, the size of the baghouse.

Dust particles collected in the baghouse will not be suitable for recycling through the sinter plant and blast furnace. The dust particles are very fine

and difficult to handle, but most importantly the elements which make up the dust-zinc, lead, sulfur, phosphorus, sodium and their compounds--will cause problems in the operation of the blast furnace. Zinc in the blast furnace burden will accelerate refractory failure and cause scaffolding. It has also been known to cause breakage of coolers, failure of the iron shell, fill the gas offtakes, and block the bells. The scrap for charging the furnace at ELFOULADH will contain zinc from the recycled galvanized steel.

There are no known economical methods for separating the nonferrous elements from the iron oxides, and the relatively small quantity of dust collected from a 15 tonne capacity furnace would not justify the expense, in any case. The dust will have to be disposed of in a properly designed and operated landfill.

3.2.9 Blast Furnace Cast House - Particulate Emissions

The cast house emissions at ELFOULADH were not particularly obnoxious so correction is not a high priority. The following discussion is presented for information and reference.

Casthouse emissions control is receiving increasing attention in the industrialized nations. Most Japanese blast furnaces have capture equipment in place. In 1982, 57 percent of the furnaces (100 percent of operating furnaces) in the USA will have equipment in place; and in Europe many furnaces are equipped or in the process of being equipped.

During tapping of the molten iron, exposure of the iron and slag to the oxygen of the air and lancing the tap hole results in the emission of fugitive particulate. The magnitude of the emissions varies with each furnace and each cast; but at one large furnace, the particulate averages 0.65 Kg per metric ton of hot metal.

There are three general methods, with variations, used to capture the fugitive particulate--total evacuation, local hoods, and noncapture

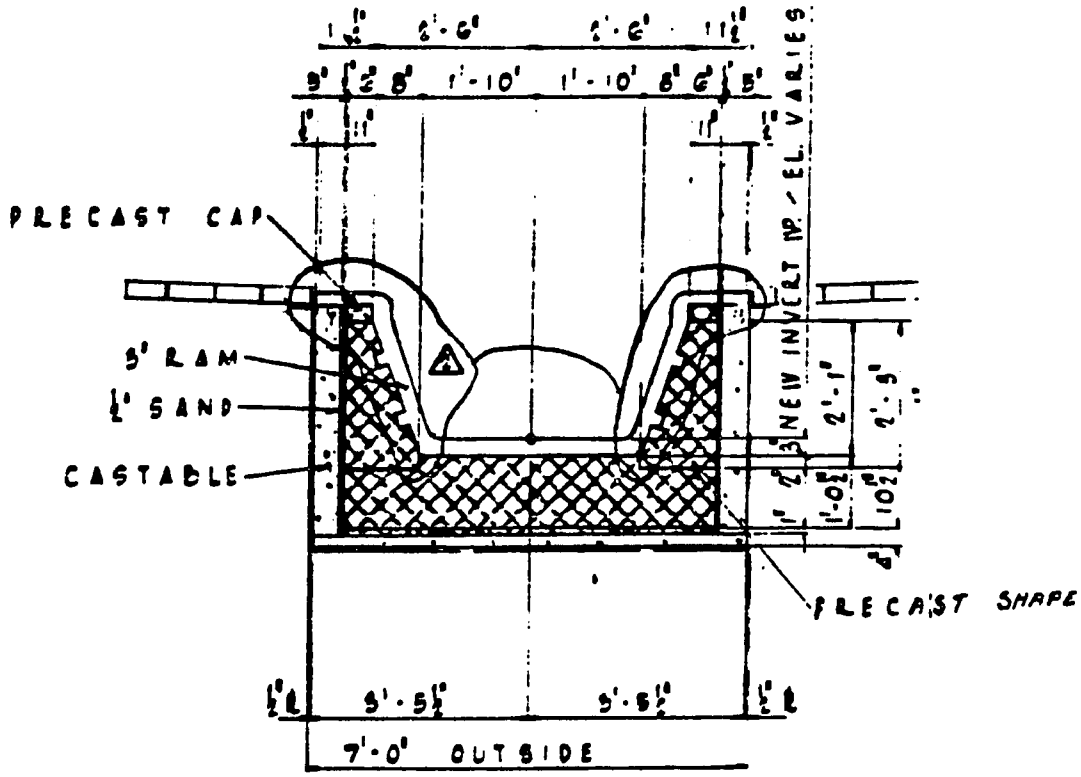
shrouding systems. In the total evacuation system, the full cast house air volume is evacuated at a rate of one to two air changes per minute. This is the most costly of the alternatives from both capital and operating costs. Energy costs are particularly high. Only a few furnaces utilize this method to control the cast house emissions and it is not recommended for ELFOULADH.

The second method, local hoods, is the most extensively used of the operating systems. There are several variations of the hood system. One variation consists of a hood about two meters above the tap hole, covers over the iron pool and dam, over the iron and slag runners and evacuation hoods over the iron pool, iron and slag spouts. The gas cleaning system is usually a baghouse, but wet scrubbers and electrostatic precipitators have been used. In this system, the hood at the iron trough, adjacent to the tap hole, is removed for drilling and plugging.

Such a system can be very effective in capturing about 100 percent of the emissions except while lancing the tap hole when the capture rate may drop to 70 percent.

The most recent technology for cast house fugitive emissions is noncapture shrouding systems. There are several variations of this technology, but the basic premise is to keep oxygen away from the molten iron and slag. The technology is at present, of a proprietary nature; however, it is available for a licensing fee.

In one system, the iron pool and runners are covered with closed, refractory lined hoods to exclude air. The runners and trough are lined with precast, high temperature, long life refractories. The precast shapes can be furnished in a single or two piece configuration. Refer to Sketch 22084-SK1. The runner refractories remain hot between casts and it is claimed that this allows for better separation of the iron and slag and permits the metal to flow without skulling (freezing). This system eliminates energy costs from the baghouse and exhaust fans and reduces maintenance of the runners. There is less deterioration of the refractories because there is a



SECTION A-A
TYP. THRU IRON TROUGH
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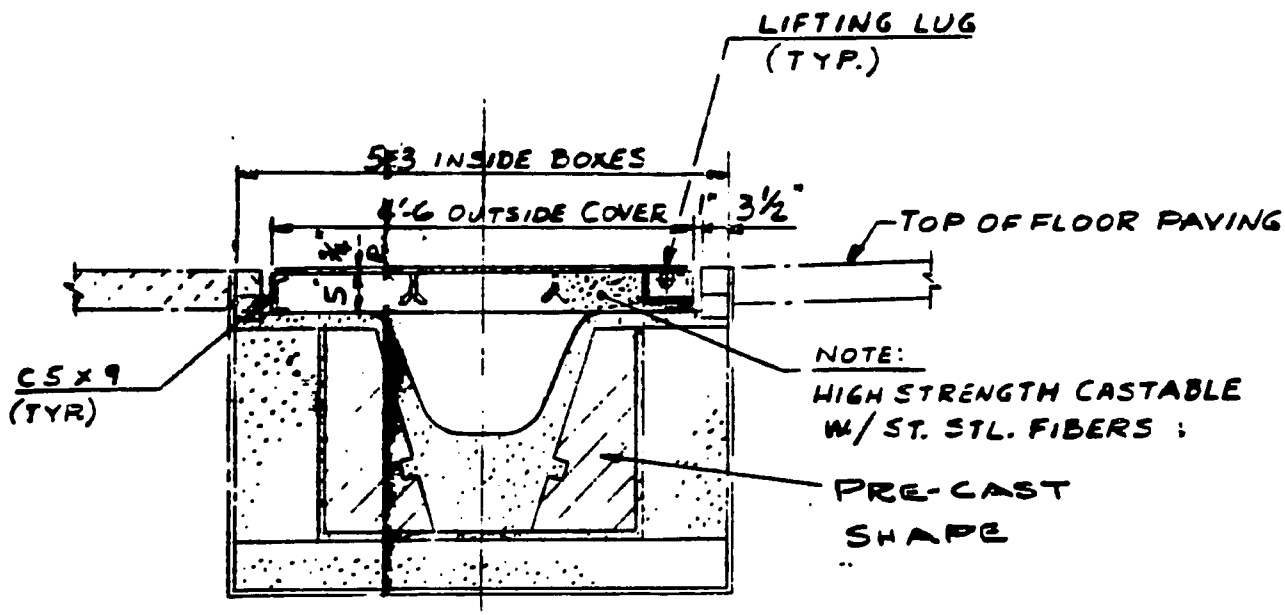

⚠ SECTION A-A
TYPICAL RUNNER SECTION

KOPPERS

SKETCH 22084SK1 50

decrease in temperature fluctuations between casts and the higher duty refractory is better able to resist chemical attack. The trough covers are mounted on monorails and use electric drive winches which can remove or replace the covers in five seconds. Cover bases are sealed with sand after each change. Operating costs will be substantially less than for the hood system described above.

A variation of the above noncapture shrouding system is to use a gas flame or steam blanket to exclude air at the tap hole and at the iron and slag spouts. The runners have simple, refractory lined covers as shown on sketch sheet 22084-SKI. As with the previous system, high temperature, single or two piece, precast shapes are used in the runners.

There is some indication that the noncapture shouded systems will result in a small increase in hot metal yield and higher temperature of the hot metal delivered to the LD shop.

3.3 Water

3.3.1 General

The quality of water at the plant has an impact on the utilization of water as a process fluid, and as a source of environmental pollution. Effluent from the facility has the potential to degrade both ground and surface waters. In order to establish a baseline against which to judge the quality of effluents, we have included as an attachment to this report a copy of Quality Criteria For Water, U.S. Environmental Protection Agency, Washington, D.C. 20460 USA, July 1976 (U.S. Government Printing Office, Washington, D.C. 20402 USA, Stock No. 055-001-0104-4). That document provides a basis for judgement in the United States for programs that are associated with water quality considerations.

The plant water system is designed to utilize the water as efficiently as possible since the supply is not overly abundant. Segregation of the various water streams with subsequent treatment and recirculation is practiced wherever possible.

The major source of water for the plant is from the National Water Distribution System. This water is a combination of well and dam water. The maximum usage rate is 400 m^3/hr. City water from Menzel Bourguiba is also supplied on an intermittent basis.

The plant makeup water is treated, filtered, and a portion softened for use in the LD furnace cooling system. The water for steam generation and a portion of the water for continuous casting is demineralized. Hypochlorite treatment is provided for the plant potable water. This system is designated as circuit #1. The plant process water is divided into three circuits (2, 3, and 4), which are arranged in a cascade type system. Each circuit is a recirculating loop with the blowdown from the decantation basin going to a lower quality water circuit.

Circuit 2 provides cooling water to the pusher furnaces, oxygen plant, sinter plant and other miscellaneous users. Makeup for the continuous casting cooling loop and the rolling mill tower is also drawn from this circuit. The makeup rate to circuit 2 is 150 M^3/hr. Plant personnel indicated that the water treatment system for the continuous casting plant was experiencing difficulty. The water which is recirculated is treated and filtered. Oil which is entering the water has been fouling the filters, thus requiring frequent backwash.

Circuit 3 furnishes cooling water for the blast furnace cascade and supplies the slag notch and tuyere coolers.

Circuit 4 is the blast furnace gas cleaning system water supply. The particulate removal device is a venturi scrubber. The contaminated water is pumped to a clarifier where the overflow is recycled back into the system. The underflow is sent to a static filter. The blowdown from this circuit is used to quench and granulate the slag. The excess water from the slag quench, approximately 80 M^3/hr, is sent to a treatment system where ferrous sulfate is used to fix the cyanide present. After treatment the stream is discharged to Lake Bizerte.

The pickling and galvanizing operation generates a liquid waste stream consisting of contaminated rinse water and the spent pickle liquor. This effluent is presently neutralized and discharged to the lake. The plant personnel indicated that some difficulty was being experienced in the neutralization step.

The following section (3.3.2) of this report will present suggestions and recommendations for upgrading ELFOULADH's water treatment facilities. The discussion will deal mainly with the treatment of the slag granulation waste water, pickling wastes neutralization and the continuous casting circulating water.

Since a minimal amount of data was available, the discussions and recommendations in this section are based on "typical" influent and effluent

quality criteria for steel plants in the United States. The source of these "typical" compositions is the U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category. Since each steel plant will have specific operational conditions that will affect the wastewater characteristics, the typical composition used in this section may not adequately represent the wastewater streams at the ELFOULADH plant. After a review of the data from the water quality monitoring program outlined in Section 4.3, the adequacy of the assumed compositions can be determined.

As discussed in Section 3.1, the cost estimates provided in this section should be considered very preliminary. They are included to give the relative magnitude of the cost for pollution control equipment and do not include site specific costs such as piping, foundations, supports, electrical equipment, or installation labor. Additional data and a detailed engineering study are required to establish a complete cost estimate.

It should be noted that due to the short period of time spent reviewing the water system at the plant site, there may be discrepancies between the information in this section and the actual conditions. If, in some instances, this is the case, an apology is offered. Nevertheless, it is believed that the discussion provided will be of interest and value.

3.3.2 Wastewater Treatment Conceptual Design Recommendations

The following presents suggestions, operational modifications, and conceptual design recommendations for treatment of:

(1) Blast furnace gas cleaning and slag quenching wastewaters,

(2) Pickling liquor wastewaters, and

(3) Continuous casting spray chamber circulating water.

During the recent plant visit by Koppers personnel, these four streams were designated as being problem areas.

A conceptual design and brief description of each respective treatment scheme needed for these waste streams follows. Wherever possible, an itemized cost estimate for each design is also given. The designs are based on limited data resulting in numerous assumptions being made. Due to this fact, equipment sizing may not be realistic. Only through plant wastewater characterization and treatability studies can the information needed for technically and economically attractive solutions be obtained. On-site plant studies also serve to supply information which can be used to determine any process changes that will reduce wastewater flowrates along with possible reuse of treated wastewaters as cooling waters. Reduced wastewater flowrates result in smaller sized treatment equipment and less treatment chemical usage. Thus, both capital and operating treatment costs are reduced. Specifics of a plant water quality monitoring study are given in Section 4.3.

3.3.3 Treatment of Blast Furnace and Slag Granulation Wastewater

Existing Treatment Process

The present blast furnace treatment system entails venturi scrubbing of contaminants and solids from the blast furnace gas stream. The liquid stream flows from the scrubber to a pumping sump, then to a clarifier for suspended solids removal. A chemical coagulant (NALCO 4047) is added ahead of clarification to enhance suspended solids removal. Overflow from the clarifier passes through a cooling tower before being recycled back to the venturi scrubber. Settled solids from the clarifier are thickened in a settling basin with the supernatant added to the clarifier overflow and recycled. The solids are returned back to the sintering plant. Blowdown from the scrubber water is used for slag granulation, then treated and discharged to Lake Bizerte. The treatment involves mixing of the wastewater with lime $Ca(OH)_2$ and ferric sulfate ($FeSO_4$), followed by

settling of suspended solids prior to discharge. The settled solids are disposed of on the plant site.

Possible operational problems associated with the existing treatment system may include:

1. Operation of the recycle scrubbing water clarifier. Solids removal could possibly be enhanced by more efficient mixing of the coagulating chemical (NALCO 4047) and the scrubber water. A proper mixing scheme includes: complete mixing of the chemical and cooling water for one minute, slow mixing at 30 rpm (flocculation) of the chemical and cooling water for 20 minutes, and finally settling of the coagulated solids. Flocculation of the wastewater and chemical causes an increase in the size of suspended particles by bridging individual particles into a larger and denser settling mass, thus enhancing settleability of the suspended solids.

2. Mixing in the slag granulation wastewater treatment process.

   Lime $Ca(OH)_2$ addition, along with a subsequent wastewater pH increase results in heavy metal precipitation and removal. But only through the proper mixing scheme (as described for the scrubber recycle water clarifier) can metals removal with lime be optimized.

3. Cyanide fixation as iron cyanide resulting from the addition of ferric sulfate ($FeSO_4$) to the slag granulation wastewater. Iron and cyanide together in a wastewater stream form soluble complexed iron cyanides (ferrocyanide and ferricyanide). These particular complexed species are difficult to remove. Total cyanide includes both free cyanide and complexed cyanides. Free cyanide is extremely toxic to aquatic organisms whereas iron complexed cyanides represent a less toxic form. Free cyanide can also be destroyed very efficiently by chlorination and non-iron complexed cyanides. A consideration with the existing treatment system is the formation of iron cyanides. Once discharged to Lake Bizerte, iron cyanides are broken down by

ultraviolet light from the sun into free cyanide. The free cyanide form can then be very toxic to aquatic organisms. Evidence of this toxicity, e.g., fish kills, may not be apparent because aquatic organisms avoid toxic conditions and they would not travel in regions of Lake Bizerte with relatively high free cyanide levels. For this reason, consideration should be given to removal of all forms of cyanide before discharge to the lake.

4. Decreasing the recycled cooling water blowdown rate. With more efficient suspended solids removal in the venturi scrubber clarifier, it may be possible to increase the cycles of concentration of the cooling water, and thus decrease the blowdown rate. Subsequently, the blowdown to the slag granulation could be distributed evenly over the hot slag in a manner that increases the amount of granulation water evaporated. These two operating changes will serve to decrease the quantity of wastewater requiring treatment before discharge to the lake. If the estimated recycle cooling water flowrate of 300 M^3/hr and a blowdown rate of 80 M^3/hr are typical, then reducing the blowdown rate by the methods described above should be seriously considered. It also may be very possible to treat the wastewater after slag granulation to a degree whereby it can be reused in a plant cooling water system. The actual degree of treatment needed will depend upon the specific cooling water system and the degree of treatment required. The information needed for such an evaluation can only be determined by on-site plant studies.

Proposed Treatment Processes

The existing treatment system handling blast furnace scrubber water appears to be fundamentally sound, but may be enhanced with certain modifications. The following process changes represent only minimal additions needed to the existing process to increase treatment efficiency. These include:

1. Mixing of the venturi scrubber water and the NALCO coagulating chemical before clarification. This process provides for the scrubber water and the chemical to be combined and completely mixed by an in-line static mixer. The flow is then flocculated in a separate tank by a low rpm mixer, and finally the solids and clarified liquid are separated by gravity in the existing clarifier. The underflow solids stream is pumped to a gravity thickening tank or basin. The overflow from the thickening tank is sent back to the recycle scrubber water sump and the thickened solids sent to the sintering plant.

   Table 3.3.1 gives the sizing and itemized cost of the additional equipment needed to increase suspended solids removal from the recycled scrubber water. Also given in the table are the assumptions made in order to estimate the equipment sizes. The possibility of modifying the existing clarifier to also serve as the floccuation chamber can be examined only by a plant study.

2. Treatment of cooling water blowdown after slag granulation. As illustrated in Sketch 3.3.1, blowdown after slag granulation goes through alkaline chlorination, breakpoint chlorination, dechlorination, heavy metal precipitation by pH adjustment with lime, neutralization, sand filtration, and finally, lake discharge. Sludge generated from this process can be handled in the same manner as is presently done, or may be thickened and dewatered in a separate sludge handling system if an economic evaluation proves it to be feasible. Refer to Section 3.3.2.4 for discussion of sludge dewatering. Alkaline and breakpoint chlorination entail the addition of chlorine to two tanks in series. The pH of the first mixing tank is to be maintained at 10 or greater. Here, the chlorine oxidizes the free cyanide (HCN, CN^-) and non-iron complex cyanide. Overflow from this tank is pumped to a second tank with the pH maintained within a range of 8.2 to 8.6. Any ammonia present is oxidized to nitrogen gas with some organics present (e.g., phenol) oxidized to carbon dioxide and water. In the United States, chlorine addition is typically accomplished by the injection of chlorine gas into the mixing tanks,

TABLE 3.3.1

ELFOULADH STEEL PLANT, TUNISIA
EQUIPMENT LIST FOR SUSPENDED SOLIDS REMOVAL
FROM VENTURI RECYCLED SCRUBBER WATER

I. ASSUMPTIONS MADE FOR EQUIPMENT SIZING

a. Recycle Water Flowrate (estimate from process flow diagram for ElFouladh Plant)

Q_r = 300 M^3/hr

b. Total Suspended Solids in Scrubber Water[1]

TSS_i = 1340 mg/L

c. Total Suspended Solids in Clarified Effluent

TSS_e = 50 mg/L (based on average solids concentration from clarifier overflow)

d. Sludge Pumping Rate from Clarifier Underflow

Q_w = 19.35 M^3/hr (based on 2% solids in clarifier underflow)

e. Sludge Production from Settling Basin to Sintering Plant

P_s = 9.68 M^3/hr (assumes sludge thickens to 4% solids concentration)

f. Estimate of Polymer Usage

Q_p = 3 kg/hr (assumes polymer dosage of 5 mg of polymer per liter of wastewater)

II. EQUIPMENT	COST
a. In-line Static Mixer	$ 600
b. 100 M^3 Flocculation Tank with Flocculator Motor	7,000
c. 2 M^3 Chemical Mix Tank with Metering Pump for Polymer Addition	2,000
TOTAL	9,600(2)

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. II, Table VIII-3, p 356.

(2) Equipment Cost Only

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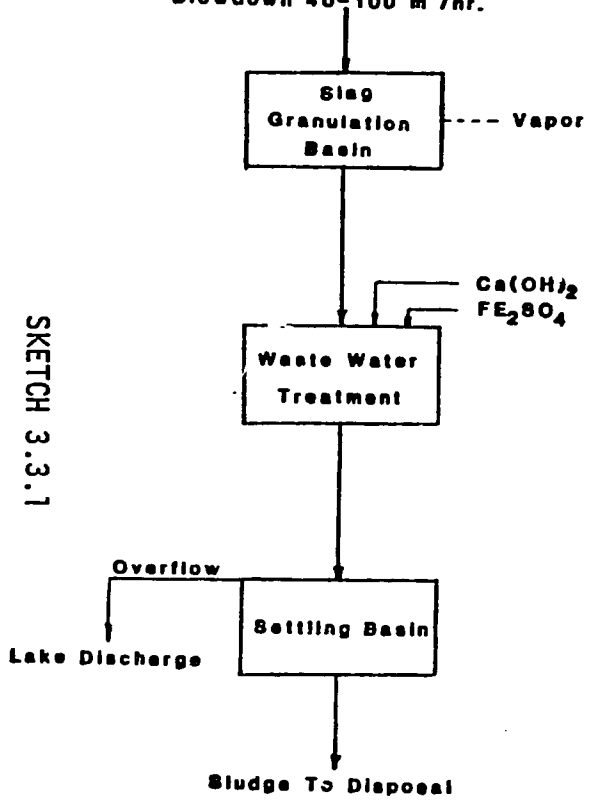
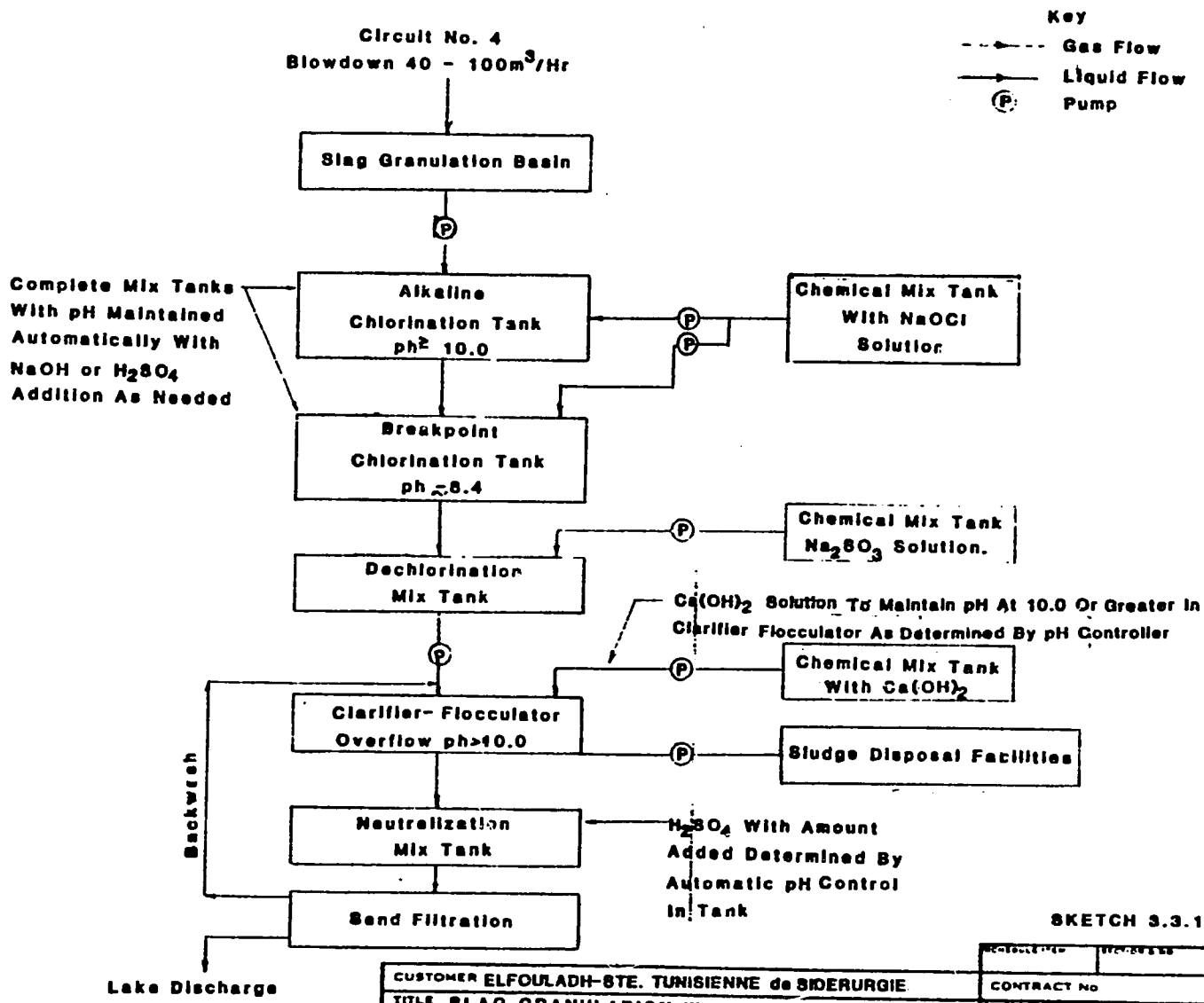
CALCULATIONS
Name Date
Made
Checked

PRESENT TREATMENT



PROPOSED REVISION



SKETCH 3.3.1

SCHEDULE NO | REVISIONS
CUSTOMER ELFOULADH-STE. TUNISIENNE de SIDERURGIE
CONTRACT NO
TITLE SLAG GRANULATION WATER TREATMENT
SHEET NO | NO OF SHEETS

SKETCH 3.3.1

or by the addition of a liquid such as sodium hypochlorite (NaOCl) into the mixing tanks. For the design given here, the addition of NaOCl is assumed but Cl_2 gas may prove more economical once a detailed design is developed. One possible concern with chlorine addition is the formation of chlorinated hydrocarbons which are suspected carcinogens. However, recent pilot plant studies conducted in the United States "Show negligible chlorinated hydrocarbon formation."[1] Hydrogen peroxide (H_2O_2) or ozone (O_3) may be substituted in place of chlorine as suitable oxiding agents for cyanides but not ammonia.

After breakpoint chlorination, any residual chlorine present in solution is removed (dechlorination) in another tank with sodium sulfite (Na_2SO_3). Here, the remaining chlorine is reduced to chloride ion and the sulfite (SO_3^{-2}) ion converted to sulfate (SO_4^{-2}). Dechlorination is necessary to remove residual chlorine substances which are very toxic to fish.

After dechlorination, heavy metals are removed by pH adjustment with lime. This entails complete mixing of the lime and wastewater followed by flocculation and settling of the metal sludge along with other settleable solids. Metal flocculation and settling can be achieved in a clari-flocculator. This is one tank which is divided into separate sections for complete mixing, flocculation, and settling. The treated clarified effluent is neutralized with sulfuric acid (H_2SO_4), passes through sand filtration, and is finally monitored for flowrate and sampled for water quality testing before discharge to Lake Bizerte.

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[1]U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. II, U.S. Government Printing Office, p. 346.

Table 3.3.2 lists the equipment sizes and itemized cost of the various treatment process components required along with the estimates and assumptions made to determine sizing.

Table 3.3.3 gives the influent and treated effluent wastewater quality expected for the proposed treatment scheme. As indicated, this process greatly reduces the pollutant loading to the lake. The individual treatment process components comprising this treatment scheme represents known technological principles presently practiced in the United States.

Cost Estimate

The total equipment cost for upgrading the blast furnace scrubber water treatment process is estimated at $86,000. Refer to Tables 3.3.1 and 3.3.2 for an itemized list of equipment. The cost is only an approximation, and does not include installation costs such as labor, pumps, piping, controls, valves, and foundations. Plant study results can be used to optimize the treatment process by modifying and using existing equipment (e.g., existing treatment basin) and by reducing the wastewater flowrate wherever possible.

3.3.4 Treatment of Acid Pickling Wastewaters

Existing Treatment Process

There exist three separate pickling operations at the ELFOULADH Steel Plant. These include: an H_2SO_4 pickling operation for continuous copper coating of wire, an HCl pickling operation for continuous galvanizing of structures, and an HCl pickling operation for continuous galvanizing of wire. Wastewater streams from all three operations are comprised of continuous rinse wastewaters and spent concentrated pickle liquor. Fume scrubber wastewater is also generated from the continuous wire plant

TABLE 3.3.2

ELFOULADH STEEL PLANT, TUNISIA
EQUIPMENT LIST FOR TREATMENT OF SCRUBBER WATER
BLOWDOWN AFTER SLAG GRANULATION

I. ASSUMPTIONS MADE FOR EQUIPMENT SIZING

a. Flowrate

Q_T = 80 M^3/hr (estimate from process flow diagram for ElFouladh Plant)

b. Estimate of Water Quality Parameters both Before and After Treatment

See Table 3.3.3

c. Chlorine Required for Both Alkaline and Breakpoint Chlorination as NaOCl

NaOCL = 70 kg/hr (for ammonia, cyanide, and phenol removal)

d. Sodium Sulfite Required for Dechlorination

Na_2SO_3 = 1 kg/hr

e. Sludge Pumping Rate from Clari-Flocculator Underflow

Q_u = 0.4 M^3/hr (assumes 2% solids in clarifier underflow)

f. Sludge Production from Clari-Flocculator After Thickening

P_S = 0.2 M^3/hr (assumes sludge thickens to 4% solids concentration)

NOTE: Usage of H_2SO_4, $Ca(OH)_2$ and NaOH cannot be estimated without a wastewater characterization and wastewater treatability studies.

continued

TABLE 3.3.2 (continued)

ELFOULADH STEEL PLANT, TUNISIA
EQUIPMENT LIST FOR TREATMENT OF SCRUBBER WATER
BLOWDOWN AFTER SLAG GRANULATION

II. EQUIPMENT	COST
a. 50 M^3 Alkaline Chlorination Tank with Mixer----------	$20,000
b. 50 M^3 Breakpoint Chlorination Tank with Mixer----------	20,000
c. 5 M^3 Chemical Mix Tank with Metering Pumps for NaOCl Solution----------	3,000
d. 50 M^3 Dechlorination Tank with Mixer----------	20,000
e. 2 M^3 Chemical Mix Tank and Metering Pump for Na_2SO_3 Addition----------	2,500
f. Clari-Flocculator with Upflow Surface Area of 33 M^2---- (based on sludge settling rate of 2.4 M/hr)	(90,000*)
g. 5 M^3 Chemical Mix Tank and Metering Pump for $Ca(OH)_2$ Addition----------	3,000
h. 2 M^3 Neutralization Tank with Mixer----------	2,500
i. pH Control Systems for Controlling: the dosages of either NaOH or H_2SO_4 to the chlorination tanks, and dosage of H_2SO_4 to the neutralization tank, and also the $Ca(OH)_2$ dosage to the clari-flocculator. The pH electrodes will be equipped with ultrasonic cleaning to prevent electrode scaling----------	15,000
j. Downflow Dual Media Sand Filter with Area of 12 M^2----- (based on application rate of 7.2 $\frac{M^3/hr\ flow}{M^2\ area}$)	(50,000*)
TOTAL----------	$86,000(1)

* Not included in the total cost based on the assumptions that equipment in the existing cyanide treatment system would be adequate.

(1) Equipment Cost Only

TABLE 3.3.3
ELFOULADH STEEL PLANT, TUNISIA
ESTIMATE OF POLLUTANT REMOVAL EFFICIENCIES
FOR BLAST FURNACE SCRUBBER WATER
BLOWDOWN TREATMENT PROCESS[1]

Water Quality Parameter	Wastewater Stream Concentrations After Slag Granulation [(mg/L) except pH]	Wastewater Stream Concentrations After Treatment [(mg/L) except pH]	Removal Efficiency (percent)
GENERAL POLLUTANTS			
Ammonia as Nitrogen	103	<1	>99
Total Cyanide	15	<1	93.3
Phenols	4	0.1	97.5
Fluoride	20	10	50
Total Suspended Solids	50	15	70
pH	6-9	6-9	-
Hexachlorobenzene	0.01	0.01	0
2,4-Dichlorophenol	0.05	0.05	0
2,4-Dimethylphenol	0.25	0.05	80
Fluoranthene	0.08	0.08	0
Phenol	3.2	0.05	98.5
Benzo(a)pyrene	0.01	0.01	0
Chrysene	0.01	0.01	0
Pyrene	0.05	0.05	0
METALS			
Antimony	0.04	0.04	0
Arsenic	0.15	0.05	66.7
Cadmium	0.07	0.05	35.8
Chromium	0.33	0.15	54.5
Copper	0.39	0.1	74.4
Lead	14.24	0.25	98.3
Nickel	0.93	0.1	89.2
Selenium	0.06	0.06	0
Silver	0.034	0.01	70.6
Zinc	24	0.3	98.8

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. V, U.S. Government Printing Office, Table VII-6, pp 396-397.

hydrochloric acid pickling operation. General wastewater characteristics and mass loadings expected from the three separate pickling operations are given in Tables 3.3.4, 3.3.5, and 3.3.6.

The wastewater data listed in the tables indicates that the mass of pollutants are mainly generated by the rinse wastewater for all three pickling operations and also the fume scrubber wastewater for the HCl wire operation. The pollutant concentrations in the spent concentrate are generally greater than the rinse wastewaters and the fume scrubber wastewaters, but the total pounds generated per day by the spent concentrates is less than the rinse wastewaters due to the low daily average flowrates of the spent liquors. The liters per day (L/day) flowrates used to estimate the total mass of pollutants of the spent concentrates are total monthly flows distributed on a daily basis to more evenly distribute the pollutant loadings to treatment.

The present treatment methodology for all three pickling waste streams entails flow equalization, neutralization with lime, settling of solids, and finally lake discharge. Specifically, the wastewaters from both the sulfuric acid and hydrochloric acid wire pickling operations are combined in an equalization pit and treated as a single flow. The waste streams from the hydrochloric acid galvanized structure pickling operation are treated in a separate, but comparable, neutralizing treatment process. Neutralization treatment of pickling operation wastewaters is the method most employed in the United States, and represents one of the more cost effective treatment schemes. The existing neutralization system at the ELFOULADH plant represents this methodology, but minor changes may enhance its effectiveness.

Possible operational problems associated with the existing neutralizing treatment processes may include:

I. <u>Mixing of the various wastewaters in the equalization pit</u>. Adequate mixing can only be achieved by mechanical agitation. This will serve to blend the rinse wastewaters, fume scrubber wastewaters, and the

TABLE 3.3.4

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE WASTEWATER CHARACTERISTICS EXPECTED FROM
CONTINUOUS SULFURIC ACID PICKLING OPERATIONS[1]

Water Parameter	Rinse Wastewater		Spent Concentrate	
	Concentration (mg/L)	Mass Loading[2] (kg/day)	Concentration (mg/L)	Mass Loading[3] (kg/day)
Dissolved Iron	280	9.99	43,800	0.117
Oil and Grease	4.1	0.142	16.6	4.4 (10^{-5})
Suspended Solids	63.7	2.2	2706	0.0073
pH, units	1.6-6.4	-	<1.0	-
Benzene	(4)	(4)	(5)	(5)
Methylene Chloride	0.048	0.0017	0.055	1.5 (10^{-7})
Diethyl Phthalate	0.010	0.00035	(5)	(5)
Dimethyl Phthalate	(4)	(4)	(5)	(5)
Arsenic	0.33	0.011	0.2	5.34 (10^{-7})
Cadmium	0.06	0.0021	0.41	1.1 (10^{-6})
Chromium	0.98	0.0339	26	6.94 (10^{-5})
Copper	3.52	0.122	(5)	(5)
Lead	0.09	0.0031	1.19	3.2 (10^{-6})
Nickel	1.54	0.053	14.4	3.85 (10^{-5})
Silver	0.28	0.0097	0.28	7.5 (10^{-7})
Zinc	0.08	0.0028	2.5	6.67 (10^{-6})

NOTE: Flowrates obtained from plant process drawings.

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. V., U.S. Government Printing Office, Table V-3 and V-4, pp 230-231.

(2) Estimates with concentrations given and assuming flowrate = 34,560 L/day.

(3) Estimates with concentrations given and assuming flowrate = 2.67 L/day.

(4) Concentration less than 0.01 mg/L.

(5) Not analyzed.

TABLE 3.3.5

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE WASTEWATER CHARACTERISTICS EXPECTED FROM CONTINUOUS GALVANIZED HYDROCHLORIC ACID PICKLING OPERATIONS

Water Quality Parameter	Rinse Wastewater		Spent Concentrate	
	Concentration[1] (mg/L)	Mass Loading[2] (kg/day)	Concentration[1] (mg/L)	Mass Loading[3] (kg/day)
Dissolved Iron	2700	12.96	51,050	0.051
Oil and Grease	20.3	0.097	3.33	3.33 (10^{-5})
Suspended Solids	37.5	0.18	445	4.45 (10^{-4})
Chloroform	0.007	3.4 (10^{-8})	0.022	2.2 (10^{-8})
Fluoranthene	0.013	6.24 (10^{-5})	(4)	(4)
pH, units	<1.0-5.0	-	0.6-3.0	-
Methylene Chloride	0.2	9.6 (10^{-4})	0.55	5.5 (10^{-7})
4,6-Dinitro-o-cresol	0.002	9.6 (10^{-6})	(4)	(4)
Phenol	0.005	2.4 (10^{-5})	0.003	3.0 (10^{-4})
Bis(2-ethylhexyl phthalate)	0.79	0.0038	0.344	3.44 (10^{-7})
Butyl benzyl phthalate	0.006	2.9 (10^{-5})	0.011	1.1 (10^{-8})
Di-n-butyl phthalate	0.025	1.2 (10^{-4})	0.007	7.0 (10^{-9})
Diethyl phthalate	0.002	9.6 (10^{-6})	(4)	(4)
Dimethyl phthalate	0.011	5.3 (10^{-5})	(4)	(4)
Tetrachloroethylene	0.012	5.76 (10^{-5})	0.006	6.0 (10^{-9})
Trichloroethylene	0.010	4.8 (10^{-5})	0.006	6.0 (10^{-9})
Antimony	0.124	6.0 (10^{-4})	2.14	2.14 (10^{-6})
Arsenic	0.23	0.0011	0.155	1.55 (10^{-7})
Cadmium	0.005	2.4 (10^{-5})	0.12	1.2 (10^{-7})
Total Chromium	0.28	0.0013	13.0	1.3 (10^{-5})
Copper	0.60	0.0029	11.0	1.1 (10^{-5})
Lead	0.10	4.8 (10^{-4})	3.1	3.11 (10^{-4})
Nickel	0.52	0.0025	10.2	1.02 (10^{-5})
Zinc	27.1	0.13	14.7	1.47 (10^{-5})

NOTE: Flowrates obtained from plant process drawings.

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. V, U.S. Government Printing Office, Table V-8 and V-9, pp 235-236.

(2) Estimates with concentrations given and assuming flowrate = 4800 L/day.

(3) Estimates with concentrations given and assuming flowrate = 1.0 L/day.

(4) Not analyzed.

TABLE 3.3.6

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE WASTEWATER CHARACTERISTICS EXPECTED FROM THE CONTINUOUS WIRE PLANT HYDROCHLORIC ACID PICKLING OPERATIONS

Water Quality Parameter	Rinse Wastewater	Spent Concentrate	Fume Scrubber Wastewater	
	Mass Loading[1] (kg/day)	Mass Loading[2] (kg/day)	Concentration[3] (mg/L)	Mass Loading[4] (kg/day)
Dissolved Iron	358	76.3	440	12.7
Oil and Grease	2.7	0.05	63.0	1.8
Suspended Solids	5.0	0.66	353	10.2
Chloroform	9.2 (10^{-4})	3.29 (10^{-5})	0.091	0.0026
Fluoranthene	0.0017	(5)	(5)	(5)
pH, units	-	-	<1.0-3.7	-
Carbon Tetrachloride	(5)	(5)	0.004	1.2 (10^{-4})
Pentachlorophenol	(5)	(5)	0.011	3.2 (10^{-4})
Methylene Chloride	0.026	8.2 (10^{-4})	(5)	(5)
4,6-Dinitro-o-cresol	2.6 (10^{-4})	(5)	(5)	(5)
Phenol	6.6 (10^{-4})	4.5 (10^{-6})	(5)	(5)
Bis(2-ethylhexyl) phthalate	0.105	5.14 (10^{-4})	0.083	0.0024
Butyl benzyl phthalate	7.9 (10^{-4})	1.64 (10^{-5})	0.090	0.0026
Di-n-butyl phthalate	0.0033	1.05 (10^{-5})	(5)	(5)
Di-n-octyl phthalate	(5)	(5)	0.109	0.0031
Diethyl phthalate	2.6 (10^{-4})	(5)	(5)	(5)
Dimethyl phthalate	0.0015	(5)	(5)	(5)
Tetrachloroethylene	0.0016	8.96 (10^{-6})	(5)	(5)
Trichloroethylene	0.0013	8.96 (10^{-6})	(5)	(5)
Antimony	0.016	0.0032	0.103	0.003
Arsenic	0.03	2.32 (10^{-4})	0.036	0.001
Cadmium	6.6 (10^{-4})	1.79 (10^{-4})	(5)	(5)
Total Chromium	0.037	0.019	0.12	0.0035
Copper	0.079	0.016	0.31	0.0089
Lead	0.13	0.46	0.009	2.6 (10^{-4})
Nickel	0.069	0.015	0.095	0.0027
Zinc	3.59	0.022	0.46	0.013

NOTE: Flowrates obtained from plant process drawings.

(1) Based on same respective concentrations as given in Table 3.3.4 but with flowrate = 132,488 L/day.

(2) Based on same respective concentrations as given in Table 3.3.4 but with flowrate = 1,494 L/day.

(3) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. V, U.S. Government Printing Office, Table V-10, p 237.

(4) Estimates with concentrations given and assuming flowrate - 28,799 L/day.

(5) Not analyzed.

spent pickling liquors into a uniform stream more quickly, thus preventing slugs of highly acidic wastewaters from upsetting the lime neutralization chamber.

2. Mixing, flocculation, and settling in the neutralization treatment process. An efficient neutralization treatment process entails: rapid mixing of the wastewater and the lime for approximately five minutes, flocculation of the suspended solids and lime for approximately 20 minutes, and finally, settling of the settleable solids. The pH electrode for the automatic pH control system should be placed in the rapid mix chamber with the pH measured determining the lime addition. The pH electrode should also be equipped with ultrasonic cleaning and should always be kept immersed in solution to prevent drying of solids on the electrode. Upon a review of a plan view drawing of the lime neutralization process, it appears that proper mixing, flocculation, and settling is not provided for. Short-circuiting in the various treatment chambers appears evident.

Proposed Treatment Process Changes

The following additions to the existing neutralization treatment system will serve to enhance its effectiveness. These include:

1. Mechanical agitation in the equalization basin. Requires one or two mechanical agitators in this basin.

2. Mechanical agitation in the neutralization basin with better control of the lime addition through an upgraded pH control system. Requires one agitator and a smaller mixing basin. Polymer additions should also be considered.

3. Mechanical flocculation of the precipitated suspended solids after mixing requires a flocculator (slow rpm) mixer.

4. A settling chamber providing sufficient settling area.

Wherever possible, the existing treatment equipment and basins should be upgraded to provide the proper mixing and settling scheme. Due to insufficient data, it is not possible at this time to recommend specific upgrading measures. Rather, Table 3.3.7 lists the equipment and sizes needed to provide for an efficient neutralization treatment process for three separate cases. The cases include:

1. Neutralization of combined wastewaters from both the HCl and H_2SO_4 wire pickling operations. Present system.

2. Neutralization of wastewaters from HCl galvanized structure pickling operations. Present system.

3. Neutralization of combined wastewaters from all three separate pickling operations. Proposed system if proven economical.

Cases 1 and 2 represent the present flow scheme, Case 3 assumes combined treatment of pickling wastewaters. Note that Case 2 represents only a very small percentage of the treatment equipment needed for Case 1. Thus, if it is at all possible, combining all three streams, as in Case 3 should be seriously considered. Table 3.3.7 gives only estimates of the equipment sizes needed to provide adequate neutralization and treatment of the waste streams from the pickling operations. Using this information, a comparative evaluation of the existing treatment processes and equipment can be made to help determine if any existing equipment is undersized. No cost estimates for the three cases is given since that only minor modifications to the existing system may be needed to upgrade the equipment to the specifications given in Table 3.3.7.

Table 3.3.8 lists the treated wastewater quality attainable by a proper neutralization treatment system. The data given are actual values measured at a USA steel plant employing a treatment process basically comprised of equalization, neutralization with $Ca(OH)_2$, flocculation, and

TABLE 3.3.7

ELFOULADH STEEL PLANT, TUNISIA
EQUIPMENT SIZING FOR TREATMENT OF
PICKLING OPERATION WASTEWATERS

Equipment Description	Equipment Size		
	Case 1	Case 2	Case 3
Equalization Tank (mixer to be included)	290 M^3	34 M^3	324 M^3
Mixing Tank Volume for Lime and Wastewater (mixer and pH electrode to be included)	1 M^3	0.2 M^3	1.2 M^3
Flocculation Tank Volume (flocculation mixer to be included)	3 M^3	0.2 M^3	3.2 M^3
Settling Tank Upflow Area (assume depth of 2 M)	10 M^2	1 M^2	11 M^2
a. Waste Sludge Produced (dry weight basis)	575 kg/day	16 kg/day	591 kg/day
b. Waste Sludge Volume (assumes 4% solids concentration)	14,375 L/day	400 L/day	14,775 L/day

NOTE: Equipment based on respective wastewater data in Tables 3.3.4, 3.3.5, and 3.3.6.

CASE 1: Combined wastewaters from both the HCl and H_2SO_4 wire pickling operations. Flow = 197,336 L/day.

CASE 2: Wastewaters from HCl galvanized structure pickling operations. Flow = 4800 L/day.

CASE 3: Case 1 and Case 2 wastewater flows combined. Flow = 202,137 L/day.

TABLE 3.3.8

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE TREATED PICKLING WASTEWATER CHARACTERISTICS
ATTAINABLE WITH A PROPERLY OPERATED
LIME NEUTRALIZATION PROCESS

Water Quality Parameter	Effluent Concentration[1] (mg/L)
Dissolved Iron	0.26
Suspended Solids	8
Oil & Grease	4.3
pH, units	7.9
Benzene	0.033
Copper	0.074
Chromium	0.9
Nickel	0.37
Zinc	0.07
Fluoride	9.5

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. v, Table VIII-14, p 298.

solids settling. The wastewater pollutant concentrations before neutralization treatment are comparable to the values given in Tables 3.3.4, 3.3.5, and 3.3.6.

Specific treatment system upgrading recommendations can only be made after a complete evaluation of the existing process is conducted. The evaluation consists of on-site wastewater characterization and wastewater treatability studies. The final design recommendations will be based on study results along with an economic evaluation.

Cost Estimate

Due to lack of sufficient data, it is impossible to estimate the cost of upgrading the pickling wastewater treatment system. As mentioned earlier, all that may be needed is the installation of a few mechanical mixers in the existing neutralization basins along with further compartmentizing of the basins. Only by a plant study can a specific design be developed.

3.3.5 Treatment of Continuous Casting Spray Chamber Recirculating Water

Existing Treatment System

The present treatment process used at the ELFOULADH steel plant is basically the same as the processes used in the United States. The process includes a primary settling basin (scale pit) for suspended solids removal, with the overflow pumped through three filters in series. The treated water is then recycled through a cooling tower. Oil removal of the settling basin overflow is not provided for. Current practice in the United States is to remove floating oils ahead of the filters to prevent fouling.

Table 3.3.9 lists the average wastewater characteristics expected in a continuous casting spray chamber recirculating water. As shown, only total suspended solids and oil and grease are present in any appreciable quantities.

Possible operational problems associated with the present treatment system may include:

1. Underdesign of settling basin. This will cause a large percentage of solids to be present in the overflow, thus causing clogging of the filters. The addition of a coagulating polymer, along with a proper mixing scheme, may enhance solids settling.

2. Insufficient oil removal from the settling basin overflow. Just as with solids, oils will also cause clogging of the filters. When a wastewater containing oils goes through a centrifugal pump, emulsification of the oils can occur. Chemical addition is usually required to remove emulsified oils, which will also clog the filter.

3. Improper filter operation. In addition to solids and oils clogging the filters, it is also possible that filter problems can be attributable to undersized filters, improper backwash cycles, and even the wrong type of filters or filter material being used. Several different types of filters are used in the United States. Flat bed filters, with disposable filter belts, or deep bed filters are often used. The deep bed filters require backwashing to clean the filter media. Flat bed filters use a media which is disposed of along with the solids filtered. The deep bed filters discharge backwash waters to sludge tanks. Filtered solids are then disposed of in landfills. The capital cost of flat bed filters is approximately one-third that of deep bed filters. In addition, flat bed filters do not require the backwashing and other equipment necessary to operate deep bed filters effectively. Four casting plants in the United States presently use flat bed filters,

TABLE 3.3.9

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE WASTEWATER CHARACTERISTICS OF A CONTINUOUS
CASTING SPRAY CHAMBER RECIRCULATING WATER

Water Quality Parameter	Concentration[1] (mg/L)	Mass Loading[2] (kg/day)
Total Suspended Solids	40	327
Oil & Grease	11.5	94
pH, units	6.6-9.4	-
Parachlorometacresol	0.03	0.25
Chloroform	0.0047	0.038
2,4-Dimethylphenol	0.008	0.065
Fluoranthene	0.0055	0.045
Di-n-butyl phthalate	0.011	0.09
Di-n-octyl phthalate	0.054	0.44
Toluene	0.005	0.041
Chromium	0.012	0.098
Copper	0.027	0.22
Lead	0.0012	0.01
Selenium	0.073	0.60
Zinc	0.17	1.39

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. III, Table V-2, p 422.

(2) Computed based on concentrations given and an estimated recirculating cooling water flowrate = 8.18 (10^6) L/day. Flowrate based on flow of 5.68 (10^4) L/hr per strand. Total flow is for six strands.

thirteen plants employ deep bed filters, but nine of these plants use central treatment systems.[2]. In these cases, the deep bed filters treat other wastewaters in addition to continuous casting wastewaters. Filtration of the continuous casting discharge will remove toxic metals entrained in the suspended solids, as those metals are in particulate form rather than in a dissolved state.

In these cases, the deep bed filters treat other wastewaters in addition to continuous casting wastewaters. Filtration of the continuous casting discharge will remove toxic metals entrained in the suspended solids, as those metals are in particulate form rather than in a dissolved state.

Proposed Treatment Process

It is expected that problems presently experienced with the cooling water treatment system may be alleviated with only minor modifications. These include:

1. Upgrading of the existing settling basin to remove oils from the overflow to the filters. It may only be necessary to install a baffle arrangement in the basin to capture and remove floating oils.

2. Chemical addition and proper mixing of the influent to the basin. This may serve to enhance solids settling. It is possible that a small section of the existing basin could be partitioned off to serve as a flocculation chamber.

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[2] U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. III, Table VIII-3.

3. Filter operation. Rather than run the filters in series, parallel operation may prove more advantageous. This will serve to increase the surface loading rate to the filters and possibly increase their efficiency.

It is difficult to be more specific with regards to giving modifications aimed at increasing the effectiveness of the present treatment process due to lack of both equipment data and operational data. For this reason, Table 3.3.10 lists the treatment equipment sizes needed to effectively remove suspended solids and oil and grease from continuous casting recycle spray water. The sizes given can be compared to the existing system to aid in specifying possible treatment equipment sizing problems. Again, it should be stressed that only from data obtained by on-site water characterization and water treatability studies can efficient and economical treatment system modifications be obtained.

Table 3.3.11 lists the treated wastewater quality attainable by a properly operated treatment process handling continuous casting spray water. The data given are actual values measured at a USA steel plant, with the treatment process nearly identical to the one used at the ELFOULADH Plant. The wastewater pollutant concentrations before treatment are comparable to the values given in Table 3.3.9.

Cost Estimate

No cost estimates can be given at this time due to lack of sufficient operating and process data. Indications are that the problems experienced with the existing treatment system are more operational than with the equipment, and can be solved with minor upgrading measures.

3.3.6 Dewatering of Water and Wastewater Treatment Sludges

It is not known whether sludge dewatering is economically applicable to the ELFOULADH Steel Plant at the present time. The following discussion is

TABLE 3.3.10

EL FOULADH STEEL PLANT, TUNISIA
EQUIPMENT SIZING REQUIRED FOR EFFICIENT
TREATMENT OF CONTINUOUS CASTING
RECYCLE SPRAY WATER

Equipment	Size
Solids Clarifier Overflow Area (with skimmer)	280 M^2
a. Mass of Dry Solids Produced	327 kg/day
b. Volume of Sludge Produced (assumes 4% solids Concentration)	8175 L/day
Dual Media Downward Flow Filter Area (assume loading rate of $\frac{7.2\ M^3/hr\ flow}{M^2\ area}$)	56 M^2

NOTE: Sizing based on assumed flowrate of 8.18 (10^6) L/day and the concentrations given in Table 3.3.8.

TABLE 3.3.11

ELFOULADH STEEL PLANT, TUNISIA
AVERAGE TREATED CONTINUOUS CASTING SPRAY
WATER CHARACTERISTICS ATTAINABLE WITH A
PROPERLY OPERATED TREATMENT PROCESS

Water Quality Parameter	Effluent Concentration[1] (mg/L)
Suspended Solids	16
Oil & Grease	6
pH, units	7.6-8.1
Chromium	0.026
Copper	0.21
Lead	0.06
Selenium	0.01
Zinc	0.33

(1) U.S. EPA, Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol III, Table VIII-3, p 438.

meant only to familiarize the reader with present United States practices concerning sludge dewatering.

In the United States, the disposal of sludges from water and wastewater treatment operation represents a substantial percentage of the total treatment operational cost. Presently, sludges are either incinerated or disposed of in secure hazardous landfills. Water from these sludges (leachate) usually contains significant quantities of toxic pollutants, and measures must be taken to prevent sludge leachate from adversely affecting the environment. To this end, it is now advantageous for sludges to be mechanically dewatered to reduce the sludge volume and thus disposal costs.

The process of dewatering generally involves gravity thickening of settled solids from different treatment clarifier underflows (e.g. wasted biological sludge, lime solids, etc.) in a central tank. Here the sludge usually thickens to an average concentration of 4 percent solids by weight (40 gm/L). After thickening, the sludge is either dewatered by centrifuging or belt filtering. Centrifuging displaces the water from the sludge by centrifugal forces while belt filtering squeezes the water out of the sludge. Both processes usually concentrate the sludge to an average concentration of 10 to 14 percent solids depending upon the sludge material and operating conditions. A sludge containing 10 to 14 percent solids is no longer liquid. In most cases, polymer addition to the gravity thickened sludge usually enhances dewatering.

Based on these facts, it is possible that the volume of sludge generated at the plant can be reduced to approximately one-third (1/3) of its present value. Just considering the treatment sludges from the blast furnace operations, the pickling operations, and the continuous casting recirculating spray water, it is estimated that the volume of sludge can be reduced from an average total flowrate of 27,800 L/day of 4 percent solids sludge to approximately 9,260 L/day of 12 percent solids sludge. Only an economic evaluation can determine if dewatering should be seriously considered. The evaluation should include all appreciable quantities of sludges generated at the plant.

3.3.7 Storm Runoff Control

Present United States Practice

With regards to control of storm runoff, the USA practice is segregation of plant areas into contaminated and non-contaminated storm runoff areas. Curbing or diking of areas is used to achieve segregation.

Contaminated Runoff

Contaminated areas include plant process areas. Here it is likely that leaking pump seals, valves, etc. will contaminate the ground with pollutants, and thus runoff. Oils, suspended solids, and organics are the pollutants most likely found in contaminated storm runoff. Runoff (both storm and steam condensate) from these areas must be collected in a storm surge tank or basin, the water quality tested, and either treated or directly discharged to a lake or receiving stream depending upon the water quality results. For a large storm runoff, the dilution effect may be enough to allow direct discharge. If runoff is found to be contaminated, then treatment is required. In some cases, oil and suspended solids removal is all the treatment necessary. After treatment, the water is either discharged from the plant or used as cooling tower make-up water if the water is treated to a sufficient degree. A surge tank or basin is needed to dampen the high peak storm flows which would hydraulically overload the treatment process.

Non-Contaminated Runoff

Non-contaminated areas include roadways and tank farms where the ground is relatively free of contaminants which would be incorporated into the surface runoff. Usually runoff from these areas is discharged directly from the plant area. In some instances, monitoring is required to insure that the discharge is free of pollutants. As a preventative measure in the United States to contain spills, tank farms must be diked, with the volume of the enclosed area large enough to contain the contents of the largest storage tank plus a one-inch rainfall. Runoff from these areas can be discharged

only after water quality testing shows it to be clean enough for plant discharge. Provisions are also included to pump tank farm runoff or tank spillage to treatment if needed.

Preliminary Plant Segregation Plan

It is not possible at this time to propose a specific storm runoff segregation plan for the ELFOULADH Steel Plant. Rather, efforts should first include a plant study to determine contaminated and non-contaminated areas along with proposed measures to achieve segregation of areas. Specifics of a storm runoff segregation study are given in Section 4.3.

ELFOULADH presently has a project underway for segregation of storm runoff.

3.4 Solid Waste

Solid wastes are generated from a number of sources within the steel plant. Slags are generated at the iron and steelmaking units; dusts containing valuable iron units are collected by various dust collecting devices; sludges accumulate at the thickeners and clarifiers and in settling basins; used refractories accumulate from relining, maintenance and repair activities; shipping containers accompany the receipt of materials, equipment and spare parts.

Some of these solid wastes can be recycled or have other useful applications; the balance of the solid wastes require a method of disposal.

3.4.1 Blast Furnace Slag

Blast furnace slag has a number of useful applications. The ELFOULADH steel plant is granulating the molten slag for use as a raw material in cement manufacture, as aggregate in concrete and as a road material. Slag, which is not granulated, is used as ballast under railroad track, as a base for roadways and as a construction fill material.

3.4.2 Steelmaking Slag

Slag from the steelmaking operations--LD and electric arc furnaces--has relatively few useful applications. The property of steelmaking slag which limits its useful application is its tendency to expand in the presence of moisture. The free lime and MnO in the slag cause it to expand. The free CaO hydrates rapidly and can increase the slag volume by 10 percent in a matter of weeks. The MgO hydrates more slowly and expansion of the slag volume may continue, at a reduced rate, over several years.

Steelmaking slag is frequently stored in open stock piles for a minimum of six months to allow expansion of the volume. The slag can then be used in applications which are non-confining. These uses include railroad ballast, road shoulders, parking areas and open fill.

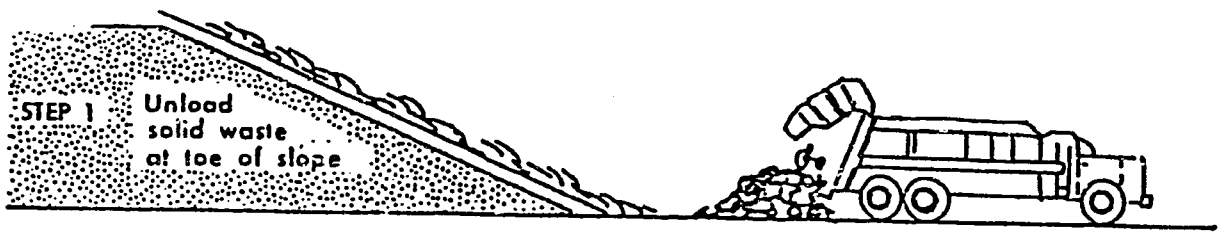
3.4.3 Sanitary Landfill

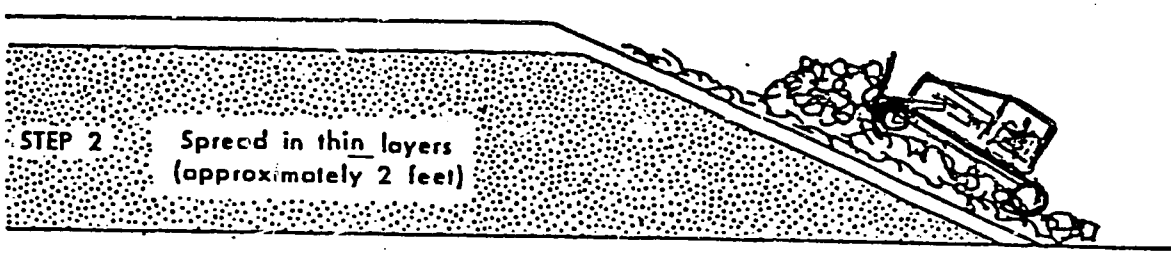
The last use, open fill, suggests an area wherein the steel plant and the city of Menzel Bourguiba can cooperate to their mutual benefit in the disposal of solid wastes. Currently, the steel plant is dumping the slag into a nearby swamp area adjoining the Lake Bizerte. The city, or individuals, are meanwhile dumping garbage in open piles in an adjoining area. These open piles are potentially a great health hazard to the populace since they are the feeding and breeding grounds for rats, flies and birds which can carry disease. These piles are also a possible source of air pollution should they be ignited. By joint effort, the swamp area, which is now a breeding place for mosquitos, can be more quickly converted from an unsuitable area to useful land for future steel plant expansion or other industrialization.

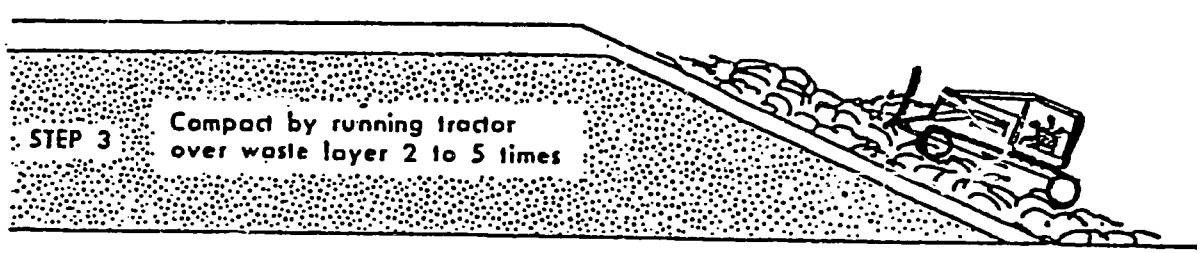
Sanitary landfilling is an engineered method of disposing of solid wastes on land by spreading them in thin layers, compacting the waste to a minimum practical volume, then covering them with soil each working day in a manner which protects the environment. Solid wastes from the steel plant can be used as a partial substitute for the soil. It is not likely that the volume of slag generated during steelmaking will be sufficient to provide all of the cover, therefore, other sources of soil cover must be located.

The following sketch illustrates the basic principles to be followed in operating a sanitary landfill. The working face should be established on a 20 to 30 degree slope with the garbage deposited at the base. The refuse is then spread in a thin layer, approximately 0.5 meter along the face of the slope and compacted by the equipment wheels which pass over it from two to five times or until the apparent compaction of the material exceeds the rebound.

A sanitary landfill handling up to 40 tonnes per day can be worked with a single crawler or rubber tired tractor equipped with a dozer blade or a landfill blade. The tractor capacity size would be about 14,000 Kg.


STEP 1
Unload
solid waste
at toe of slope


STEP 2
Spread in thin layers
(approximately 2 feet)


STEP 3
Compact by running tractor
over waste layer 2 to 5 times

3.5 Safety and Industrial Hygiene

3.5.1 General

These areas of environmental concern were given a somewhat superficial review due to the lack of time. Obviously, however, worker safety and the condition of the work place atmosphere is quite important. Worker efficiency can be adversely affected by unsafe conditions and an unpleasant work place. Lost time and accidents can also result. This situation can lead to reduced production.

During the plant tour, certain inadequacies were noted. The use of safety glasses and hard hats did not appear to be enforced, even in those areas where signs indicated that hard hats were required. There also were several open holes in the floors into which a person could fall and be injured. These were not roped off. In the structure fabrication area, worker protection, such as gloves, was not in evidence.

There were certain work places in which the conditions could be improved. The area which should receive attention first is the structure galvanizing plant. The zinc fumes were quite noticeable in this building. Dust and fumes which occur in iron and steel making operations were in evidence in the blast furnace casthouse, but were not particularly obnoxious. Casthouse emission control was discussed in Section 3.2.9.

In Koppers and other United States plants, it is the responsibility of plant management to establish and enforce requirements, which provide for worker safety and exposure.

3.5.2 Safety Recommendations

This section will present Koppers plants organization and approach to plant safety rather than specific recommendations for various hazards. This may present some new thoughts which could be incorporated into ELFOULADH's safety program. The hazardous gas area at the blast furnace top will be reviewed separately indicating United States safety practices.

Koppers has, at each plant, one person whose title is Safety Director. This individual reports to top plant management. It is his responsibility to maintain a safe operating plant. Two safety meetings are held per month, one of which includes the union safety committee leader. The director is also responsible for industrial hygiene.

Each plant has a booklet entitled, "Plant Safety Regulations." A copy of the index of these regulations is shown in Exhibit 3.5. Each new employee receives a copy of the safety regulations and is responsible for adhering to the regulations. Exhibit 3.5.1 indicates the contents of the Index, Section K, Protective Clothing and Equipment. The safety requirements are enforced and repeater offenses can require time off. While this information is not specific to steel plants, it presents requirements generally applicable to any industrial facility.

There are other aids to the plant safety program. These include Material Safety Data Sheets and data from the National Safety Council. Examples of this information are shown in Exhibits 3.5.2 and 3.5.3. These are safety data sheets for hydrochloric and sulfuric acid.

The gas hazard which exists at all blast furnaces is due to possible gas leaks which contain 24% to 28% carbon monoxide. Carbon monoxide combines with the hemoglobin of the blood and prevents it from carrying oxygen to the tissues. Depending on the carbon monoxide concentration, the effect can range from headaches and dizziness to suffocation.

Koppers practice normally classifies the hazardous gas areas as being from the casthouse floor to the furnace top, around the furnace proper. No access is permitted to the furnace top during operation. Workers in hazardous gas areas are required to carry carbon monoxide monitors and portable fresh air escape devices. Exhibits 3.5.4 and 3.5.5 describe the monitor and escape device.

3.5.3 Industrial Hygiene Recommendations

This section deals with the area at the plant which appeared to have a poor work place atmosphere. The facility is the structure galvanizing plant.

3.5.3.1 Galvanizing Plant

The fumes from the galvanizing bath operation are quite corrosive and obnoxious. In addition, the zinc present could cause what is commonly called zinc fume fever. There are documented accounts where workers when exposed to zinc fumes, experience a condition similar to influenza. It is recommended that this situation be corrected.

There are, no doubt, a number of possible solutions to the fume emission, including the use of personnel protection, i.e. respirators, air curtain over bath and an exhaust system. Plant personnel indicated that it is difficult to get workers to use respirators. The present plant thinking is to install an air curtain on the bath.

Since Koppers experience with air curtains has not been successful, it is recommended that a slot-type ventilation hood be considered. Since the fumes are quite corrosive, fiberglass reinforced plastic duct work, fan, and housing should be used. If this material is not available, galvanized duct coated with Koppers' bitumastic super service black (see Exhibit 3.5.6) would be satisfactory.

Due to the overhead craneway, the exhaust duct work would be carried at floor level to the side of the building and then through the roof.

The design procedure for a slot type hood is shown in Exhibit 3.5.7. The installation of a slot hood would correct a work place problem and reduce building corrosion in the galvanizing bath area.

4.0 Baseline Data Generation

4.1 General

The environmental impact of an industrial facility, particularly an isolated source such as ELFOULADH, can best be defined by establishing the plant's impact on the ambient air and water quality by ambient monitoring. The data generated serves as a basis for determining the magnitude of the problem by comparing the data with established levels such as the USA Air and Water Quality Standards. The information is also invaluable in designing control facilities for the emissions.

Monitoring is recommended for ELFOULADH as a cost effective approach to emission control. Much of a monitoring program can normally be implemented by plant personnel depending on the quality of laboratory facilities, equipment, and personnel. In any case, an environmental consultant such as Koppers Company, Inc., Environmental Department, should be retained to prepare the monitoring plan, furnish key personnel, provide training and direct the operation.

The following sections present preliminary monitoring plans for both air and water. Since information was not obtained on the availability of either testing or analytical equipment to ELFOULADH, the necessary equipment has arbitrarily been added to the monitoring plans.

The ambient water quality study (Section 4.3) has been divided into two main sections. The first is a monitoring plan to establish the plant's effluent impact on Lake Bizerte. The second is an in-plant water/wastewater survey to obtain data which can be used to develop economical engineering solutions to problems and to optimize the plant's water usage and treatment systems.

4.2 Ambient Air Monitoring Plan

4.2.1 General

The purpose of monitoring ambient air at an industrial facility is to determine the impact of the emission sources on the environment. Comparison of the numbers generated with ambient air standards such as those established in the United States, which are based on health effects, would indicate the magnitude of the problem.

The pollutants of first concern to essentially any industrial facility are total suspended particulates and sulfur dioxide. Monitoring for these two items at ELFOULADH would establish a baseline from which decisions for control could be made. The only sources of sulfur dioxide emission in the plant are the steam generation facilities, which burn a mixture of blast furnace gas and fuel oil, and the furnaces which burn fuel oil. The environmental impact from these sulfur dioxide emissions should not be a problem. Establishing the present concentration, however, would provide a reference base for the future.

The collection of continuous air quality data requires steady, reliable monitoring to ensure data validity. Collection and processing of data can be accomplished by following specific monitoring procedures. This section has been prepared to describe how monitoring is done in the United States, and to advise how these procedures may be suited to ELFOULADH. The following subjects will be addressed:

4.2.2 Monitoring Site Location
4.2.3 Particulate Monitoring
4.2.4 Sulfur Dioxide Monitoring
4.2.5 Equipment Required and Estimated Costs
4.2.6 Air Monitoring Program Cost

4.2.2 Monitoring Site Location

4.2.2.1 Dispersion Modeling Concept

The monitoring equipment must be located in the area where the maximum pollutant concentration will occur. The location of this area is determined through the use of a computer dispersion model.

A dispersion model is a mathematical representation of the meteorological transport and turbulent diffusion processes that occur in the atmosphere. Generally, such a model relates pollutant emissions from a source, such as a stack, to the concentration at a number of points (called receptors) located at ground level within the impact area of the stack emissions.

For a given source, the data required as input to a dispersion model are average emission rates, stack heights, stack diameters, exit velocities, and exit temperatures. The input data required for receptors are the coordinate locations relative to that of the pollutant source. The parameters used to characterize meteorological processes are: wind direction, wind speed, atmospheric stability, temperature, and mixing height. Wind direction determines the direction of movement of the plume. Wind speed affects the initial dilution of the pollutant as it is emitted from the stack. Atmospheric stability determines the rate of turbulent diffusion of the plume as it moves downwind. Stability characterizes the thermodynamic structure of the atmosphere in terms of sustaining disturbances. It may be classified as stable, neutral, or unstable. Mixing height determines the depth of the atmosphere through which pollutants can be dispersed in the vertical. One year's meteorological data is required for the dispersion model run.

4.2.2.2 CRSTER Model Description

The model most suited for application at ELFOULADH is the Single Source (CRSTER) model. This model has been used primarily in simulating the

behavior of stack effluents from combustion sources. Although designated as the Single Source (CRSTER) model, the computer program offers the capability of considering up to 19 stacks simultaneously which are located at a common site.

The CRSTER model can be purchased on magnetic tape by ordering UNAMAP 4 dispersion model tape (PR81-164-600) from the following address:

National Technical Information Service
Springfield, Virginia 22161

The CRSTER program is written in Fortran V language for execution on a UNIVAC 1100 computer.

CRSTER is composed of two parts, namely, a plume rise model for estimating the effective release height of the pollutant plume from a point source, and a diffusion model to calculate the downwind dispersion of the plume. The rise of an emission plume above its source height often accounts for a significant reduction in related ground level concentrations. A sub-model in CRSTER calculates the rise of plumes under varying meteorological conditions. Representation of the transport and turbulent diffusion of a source plume is accomplished by a Gaussian plume model. This model provides a representation of the time averaged spatial distribution of pollutant concentrations downwind of a continuously emitting point source. The rate of expansion of the plume is characterized by a series of empirical dispersion coefficients which are functions of atmospheric stability and downwind distance from the source.

4.2.2.3 CRSTER Output

The output generated by CRSTER can be classified into the following two categories:

Printouts of input data
Printouts of concentration tables.

An example of the CRSTER output is included in Appendix I.

The input data printout indicates the source emission information, meteorological data for each day concentrations are calculated, receptor elevation data, and program control parameters and options.

The concentration tables printout include summaries for the highest and second highest one-hour, three-hour, and 24-hour concentrations at each receptor point. Also, a table of the 50 highest concentrations for the entire year for each averaging time is included. Annual mean concentrations at a set of 180 receptors are also printed out. The annual mean concentrations are used to establish the maximum impact area and, therefore, the monitoring site location.

4.2.2.4 Determination of Monitoring Site Location

The CRSTER output data in Appendix I will be used to demonstrate how the site location is established. The maximum impact area is schematically described by constructing an isopleth drawing using the annual mean concentrations. An isopleth drawing defines areas of equal pollutant concentrations. Figure 4.2.2.4 is the resulting isopleth from the example CRSTER run in Appendix I.

In constructing an isopleth, the grid is drawn with 36 radials (each 10° apart). The downwind ring distances complete the construction of the grid. The annual mean concentrations at each receptor computed by the CRSTER model are plotted on the grid. All the points of equal concentration are then connected. From Figure 4.2.2.4, it is apparent that the hypothetical maximum impact area is 1.2 km northeast of the source. This then would be one area in which a monitoring station would be established.

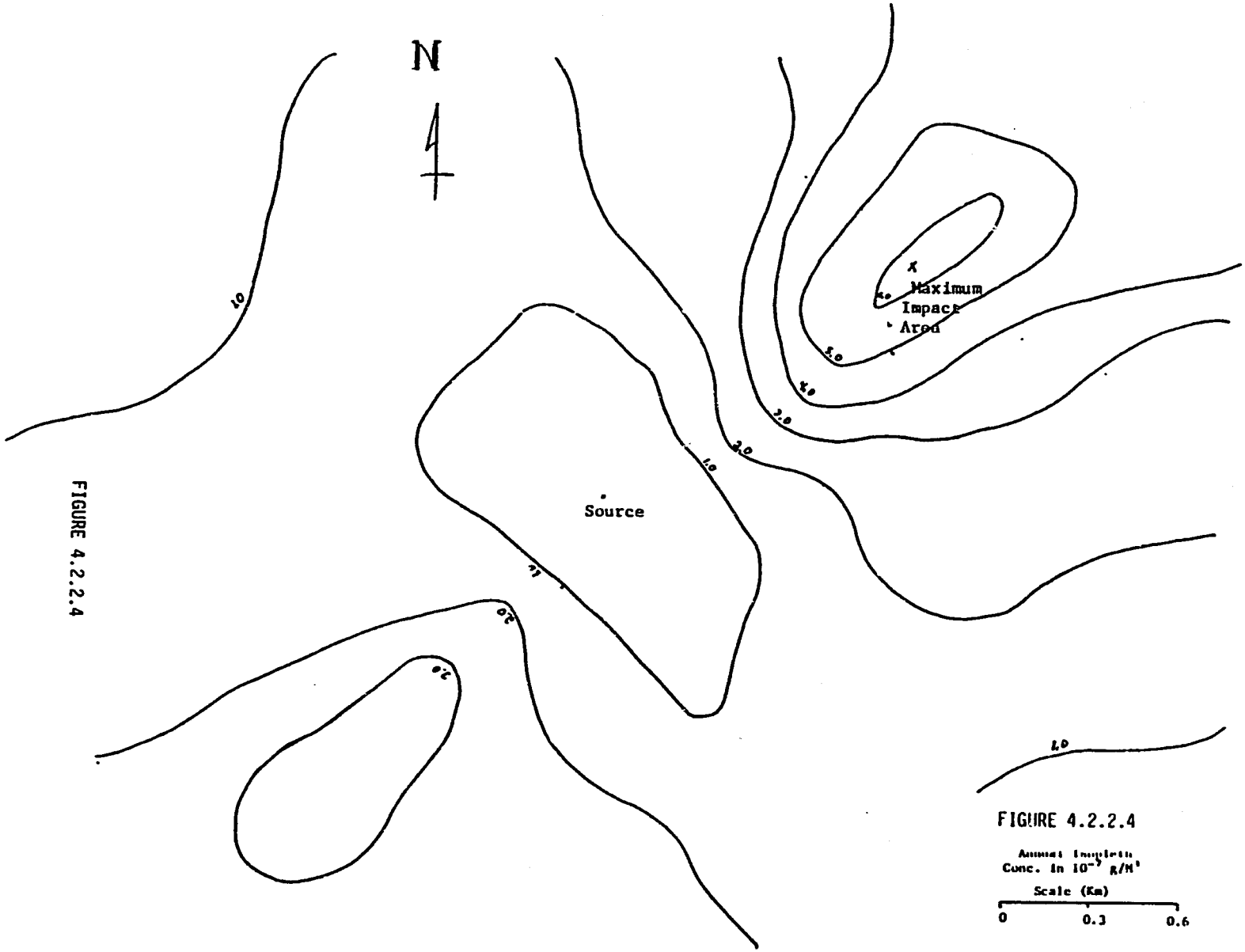


FIGURE 4.2.2.4

FIGURE 4.2.2.4

Annual Inhalation
Conc. in 10^{-9} R/M³

Scale (Km)

0 0.3 0.6

4.2.2.5 US Ambient Air Quality Standards

In the USA, the concentrations generated from a monitoring program are compared to ambient air quality standards shown below. Monitored concentrations which exceed the numbers shown are, of course, in violation. The standards are based on health criteria.

NATIONAL AMBIENT AIR QUALITY STANDARDS

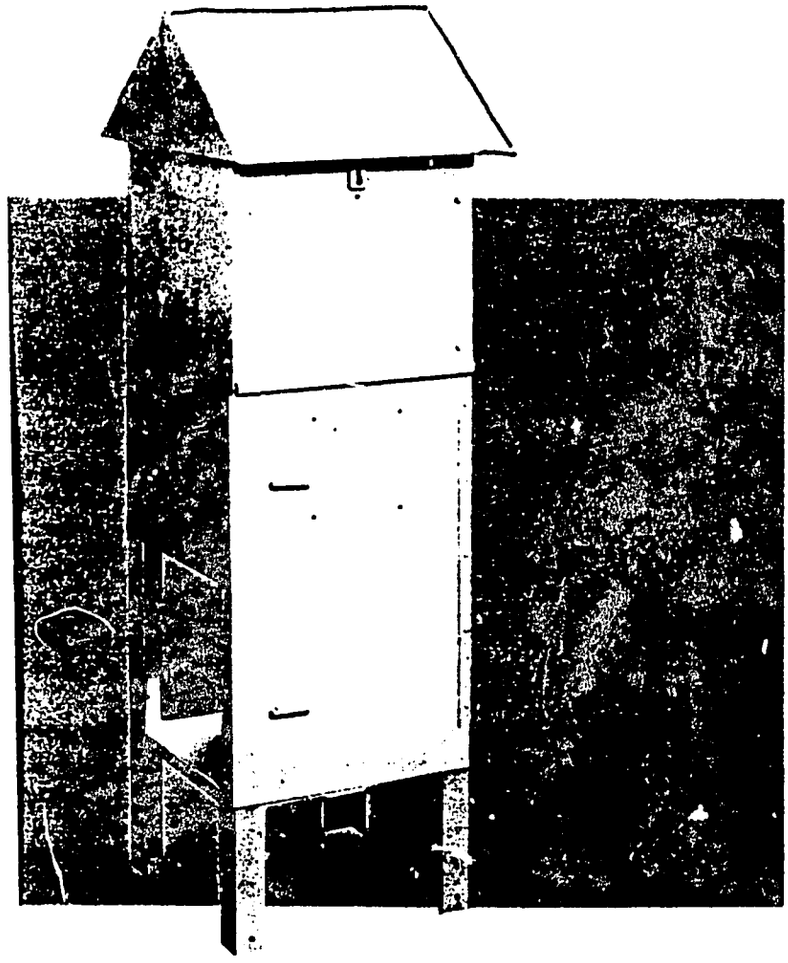
Pollutant	Averaging Time	Standard ug/M^3 (micrograms/M^3)
Particulates	Annual	75
	24-hour	150
Sulfur Dioxide	Annual	80
	24-hour	365
	3-hour	1300

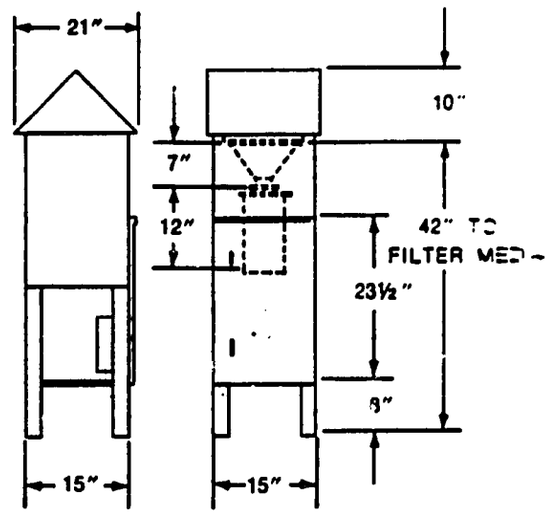
4.2.3 Particulate (TSP) Monitoring

4.2.3.1 Sampling Procedure

In order to determine the air quality impact of the source without any background interferences, monitoring for TSP is frequently performed upwind and downwind of the source. One of these TSP monitors should be in an appropriate location in order to determine the air emissions impact on Menzel Bourguiba. Monitoring will occur over 24-hour periods for the duration of one year. Monitoring for TSP is accomplished with the use of high volume samplers (hi-vol method). A picture of a hi-vol sampler is included in Figure 4.2.3.1.

Air is drawn into the covered housing and through a filter by a high-flow rate blower at 1.1 to 1.7 m^3/min. Particulates with diameters of 0.1 to 100





Hi - Vol Sampler in Operational Position

FIGURE 4.2.3.1

um are collected on glass fiber filters. When a sample is collected at an average flow rate of 1.7 m^3/min for 24 hours, an adequate sample can be obtained even in a low TSP concentration area.

The TSP mass concentration (ug/m^3) in ambient air is computed by measuring the mass of TSP collected and the volume of air sampled. Initial and final flow rate readings for each sample must be recorded in a log book which should be maintained with the sampler.

The sampling and analytical methods for TSP monitoring are in Appendix 2.

4.2.3.2 Filter Selection and Preparation

The high volume sampler filter can also be used to determine trace metals and hydrocarbons. In this case, a spectral-quality grade filter is recommended for use rather than the traditional grade filter. This filter contains less organic and inorganic contaminants, and therefore is suggested for use where additional chemical analyses are anticipated.

Each filter should be visually inspected for defects such as pinholes, tears, creases, or lumps. The filter must be equilibrated in a conditioning environment for 24 hours before weighing to minimize errors in the weight. The conditioning environment should average between 20° and 25°C with a relative humidity less than 50% without varying more than ± 5%. The tare weight of the filter is determined immediately after equilibration.

4.2.3.3 Analysis of Samples

To determine the mass of particulate, the exposed filters are equilibrated for at least 24 hours in the same conditioning environment previously described. The filters should be weighed to the nearest milligram on an analytical balance.

Trace metals such as copper, iron, magnesium, nickel, and zinc can be measured accurately to a small fraction of a mg/l by atomic absorption

spectrophotometry. In atomic absorption spectrophotometry, the element being measured is aspirated into a flame or injected into a carbon arc furnace and atomized. A light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the atomized element. Because each metallic element has its own characteristic absorption wavelength, a source lamp composed of that specific element is used to minimize spectral interferences. The amount of absorption of the characteristic wavelength is proportional to the concentration of the element in the sample.

Polynuclear aromatic (PNAs) hydrocarbons may be determined in the following manner. The filter paper containing the sample is placed in a paper extraction thimble. The thimble is dried in a hot-air oven for 30 minutes and then filled with glass wool. The sample is then extracted in a Soxhlet apparatus using methylene chloride for a 24-hour period. The resulting extract is further concentrated and the PNA concentration is established by ultraviolet and fluorescence detection methods with the High Performance Liquid Chromatography (HPLC). Column liquid chromatography is a well established separation method. A small diameter column (1-3 mm) is packed with particles of diameters less than 50 um. The effluent is pumped through the column at a high flow rate (1-5 ml/min) resulting in a significant pressure drop (7.03 Kg/cm^2 for a one meter column). The sample components migrate at different velocities through the column causing a separation. Each component peak occurs at a characteristic time as it comes off the column.

The analysis for trace metals and PNAs would be performed on a monthly basis.

4.2.3.4 Calculations and Data Reporting

At standard temperature and pressure (STP), the volume of air sampled may be determined from the following equation:

$$V = (Q_i + Q_f)/2 \quad t$$

V = Air volume sampled, m^3

Q_i = Initial air flow rate, m^3/min at STP

Q_f = Final air flow rate, m^3/min at STP

t = Sampling period, min.

The TSP sample concentration is determined by:

$$TSP = (W_f - W_i)\, 10^6/V$$

W_f = Weight of exposed filter, g

W_i = Tare weight of filter, g

All original calculations and concentration levels (ug/m^3) must be recorded in an operational monitoring log.

4.2.3.5 Model GMWL-2000 for TSP Sampling

Figure 4.2.3.5 is the manufacturer's information on a specific TSP hi-vol sampling system. The filter assembly and flow meter are housed inside an aluminim shelter for outdoor service. The power required is 115 V, 60 Hz, 3.7 amp.

4.2.4 Sulfur Dioxide (SO_2) Monitoring

4.2.4.1 Sampling Procedure

Sulfur dioxide is absorbed from ambient air into a solution of potassium tetrachloromercurate (TCM). A complex called dichlorosulfitomercurate (DSM) is formed which resists oxidation by oxygen in air. This complex can be considered stable at 25° C only during sampling. After sampling, the sample must be stored at 5°C until analysis to prevent any further degradation (thermally controlled sampling equipment is commercially available). The DSM is reacted with pararosaniline (PRA) and formaldehyde to form an intensely colored dye (pararosaniline methyl sulfonic

MODEL GMWL-2000

High Volume Air Sampling System

MODEL GMWL-2000 AIR SAMPLER

This basic unit is widely used by government and industry to collect and accurately measure airborne particulate matter by monitoring large volumes of air. Utilizing paper media, the Model GMWL-2000 traps particles as small as .01 micron in size.

Designed and built for continuous, 24-hour a day sampling, the heavy duty turbine type blower with high-speed motor is contained in a rugged but lightweight plastic housing. Four bolts, easily accessible, permit motor removal for periodic brush replacement.

The air flow rate is measured by a variable orifice meter which must be calibrated periodically to maintain on-site accuracy.

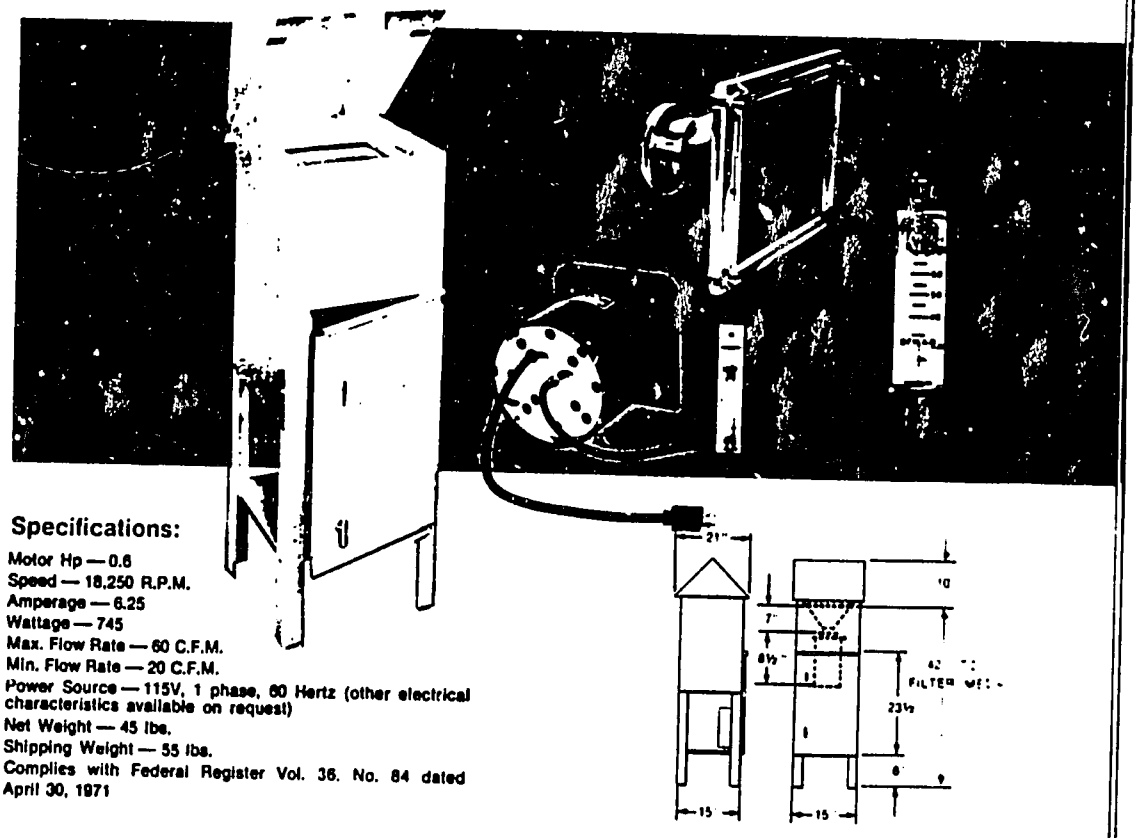
A precision bored flow meter, Model GMW 2009-2, may be substituted optionally. Encapsulated in durable acrylic, the deluxe flow meter is designed to withstand extended field service.

MODEL FH-2100 FILTER HOLDER

Designed to accommodate 8" x 10" filter paper, the Model FH-2100 Filter Holder is made of Type 304 stainless steel for maximum strength and durability. Its heavy duty seamless construction is leakproof and conical in shape for maximum support. Furnished complete with support screen and neoprene gasket for positive seal, the Model FH-2100 Filter Holder also accommodates the Model GMW-3000 Filter Paper Cartridge without modification. The filter holder attaches to the sampler with a threaded ring and gasket for easy assembly.

MODEL GMW-8500 ALUMINUM SHELTER

Heavily reinforced, the shelter is constructed of .080" aluminum anodized for outdoor service. The gable roof and large door are equipped with heavy duty aluminum hinges affording complete access to the components housed within. A horizontal baffle prevents sampler exhaust dust and aluminum hasps facilitate locking the gable roof in either the open or closed position.



Specifications:

Motor Hp — 0.6
Speed — 18,250 R.P.M.
Amperage — 6.25
Wattage — 745
Max. Flow Rate — 60 C.F.M.
Min. Flow Rate — 20 C.F.M.
Power Source — 115V, 1 phase, 60 Hertz (other electrical characteristics available on request)
Net Weight — 45 lbs.
Shipping Weight — 55 lbs.
Complies with Federal Register Vol. 36, No. 84 dated April 30, 1971

FIGURE 4.2.3.5

acid), and the absorbance of the dye is measured spectrophotometrically. The SO_2 concentration can then be related to the absorbance of the dye.

The collection method involves the use of a sampling train consisting of polypropylene bubbler tubes and critical orifices for flow control. The absorber consists of:

1) A polypropylene container that is 164 mm in depth and 32 mm in diameter.

2) A two port polypropylene tube closure.

3) A glass impinger tube that is 152 mm in length and 6 mm in diameter and that has an outlet orifice diameter that fits a No. 79 jeweler drill. The required orifice size is between 0.368 and 0.406 mm.

Figure 4.2.4.1 is a diagram of the bubbler sampling train.

As with TSP, sampling will occur over a 24-hour period for a duration of one year. One monitor should generate sufficient data.

Sampling and analytical methods for SO_2 may be found in Appendix 3.

4.2.4.2 Analysis of Samples

When the sampling period is over, the final flow rate must be checked and corrected to standard conditions. Then the average flow rate should be calculated.

Pararosaniline and formaldehyde is reacted with the absorbing solution and analyzed with a spectrophotometer. A calibration curve shows the relationship of the ug of SO_2 to the absorbance. The SO_2 concentration is calculated as follows:

$$ug\ SO_2/m^3 = 10^3(A-A_o)B_s/V_r \quad D$$

10^3 = Conversion of l to cm^3

A = Sample absorbance

A_o = Reagent blank absorbance

B_s = Calibration factor, ug/absorbance unit

V_r = The sample air volume corrected to 25°C and 760 mm Hg

D = Dilution factor (for 24-hour samples, D = 10)

4.2.4.3 RAC 3-Gas Sampler

Appendix 4 contains the manufacturer's information on the RAC 3-Gas Sampler for SO_2 collection. This system is supplied in a portable all-weather shelter model for outdoor use. It contains a thermoelectric cooling-heating system which maintains the SO_2 reagent at optimum temperature for sample stability.

4.2.5 Equipment Required and Estimated Costs

The following equipment list is based on the assumption that facilities are available in Tunisia for analysis of hydrocarbons and metals by chromotography and atomic absorbtion, respectively.

4.2.5.1 Particulate Monitoring

Item	Cost US $
Analytical Balance	4,000
Orifice Calibration Unit	120
Sampler 2 @ $420.00	820
Spectral Grade Filters	400
TOTAL	5,360

4.2.5.2 Sulfur Dioxide Monitoring

Item	Cost
	US $
Sampler	1,200
Orifice Calibration Unit	300
TOTAL	$1,500

The monitoring program recommended for ELFOULADH would tentatively consist of two stations for monitoring particulate and one station for sulfur dioxide. The stations would be operated for one year to obtain a data base.

The field work necessary would be daily visits to each station to replace filters and solutions. These would then be taken to the analytical laboratory for analysis as described in other sections of this report.

It is suggested that a consultant be retained to determine the monitoring station locations, assist in the setup of equipment and provide a start-up and training program for the operating personnel. This approach would be helpful in assuring the collection of valid data.

The cost of the initial setup and training would be $25,000 US, plus travel and living expenses. This estimate is approximate, and does not include the equipment cost indicated in Section 4.2.5.

4.2.6 Air Monitoring Program Cost

The monitoring program recommended for ELFOULADH would tentatively consist of two stations for monitoring particulate and one station for sulfur dioxide. The stations would be operated for one year to obtain a data base.

The field work necessary would be daily visits to each station to replace filters and solutions. These would then be taken to the analytical laboratory for analysis as described in other sections of this report.

It is suggested that a consultant be retained to determine the monitoring station locations, assist in the setup of equipment and provide a start-up and training program for the operating personnel. This approach would be helpful in assuring the collection of valid data.

The cost of the initial setup and training would be $25,000 US, plus travel and living expenses. This estimate is approximate, and does not include the equipment cost indicated in Section 4.2.5.

4.3 Ambient Water Quality Monitoring Plan

This section discusses the specifics of a water quality monitoring study for the ELFOULADH Steel Plant. Included are:

(1) Effect of plant discharges on Lake Bizerte.

(2) Specifics and objectives of water/wastewater characterization and treatability studies.

(3) Equipment list with itemized cost.

(4) Cost estimate of study.

The monitoring plan presented is as detailed as possible based on limited plant information. As such, the monitoring plan presented is only preliminary. The program could be broken into two separate phases. The first phase would establish the plant impact on Lake Bizerte as described in Section 4.3.1. Depending on these results, all or portions of the study presented in Section 4.3.2 could be implemented, as Phase 2, to provide design data for cost effective engineering solutions. A preliminary visit by a team of three environmental engineers is first warranted to more narrowly define the study specifics and the cost estimate. Regardless, the study proposal given here discusses the basic principles of a plant water quality monitoring study. A discussion of each section now follows.

4.3.1 Effect of Plant Discharges on Lake Bizerte

The following presents a preliminary monitoring plan for determining the impact of plant discharges on Lake Bizerte. Plant discharges include:

1. Treated and untreated wastewater streams. Continuous flow is assumed.

2. Storm runoff flows. These are intermittent flows with flowrate determined by storm intensity.

4.3.1.1 Specifics of Discharge Assessment Study

Due to insufficient data, only study generalities are given. The following is to be done for all plant discharges (both continuous and intermittent):

1. Flowrate measurment and concurrent sampling for water quality analysis of all plant discharges. Flows (both continuous and intermittent) are to be measured and recorded over a 24-hour period. This information will give daily variations in flowrates. Intermittent storm runoff flows are to be correlated with rainfall and runoff areas. Portable weirs and flowmeters are to be utilized wherever possible. Both composite or grab sampling of all plant discharges is also to be conducted.

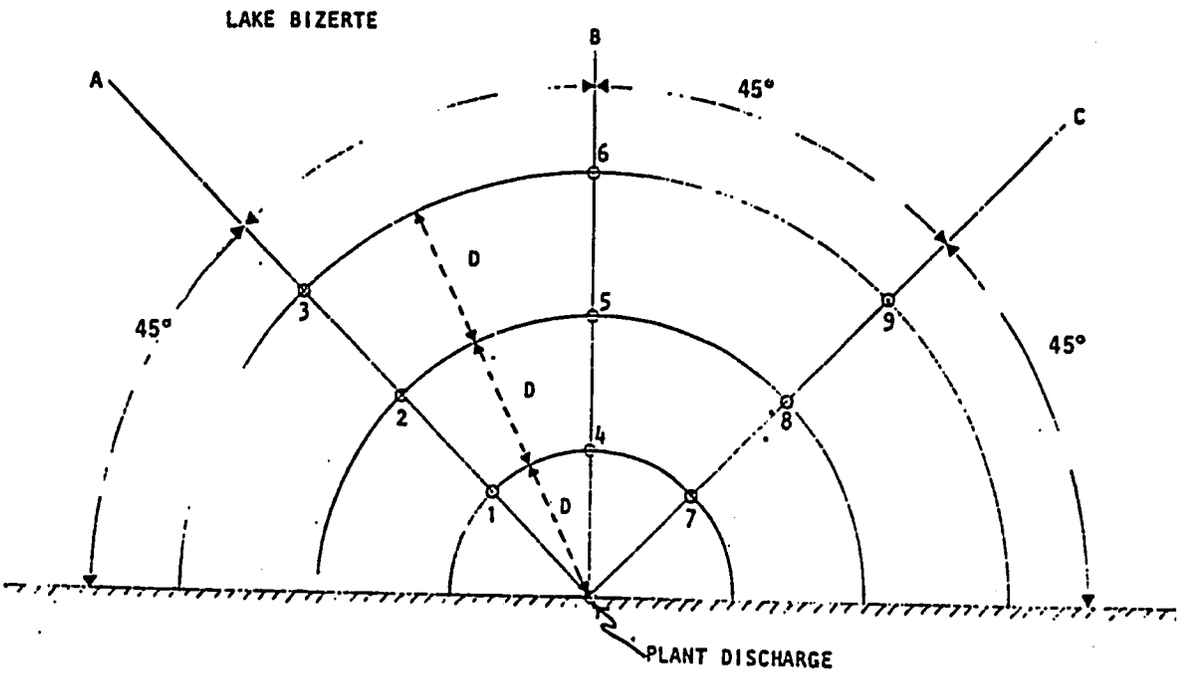
2. Dye studies of all plant discharges. By adding fluorescent dyes to plant discharges, the mixing pattern of the plant waters with lake waters can be visually determined.

3. Lake sampling near the vicinity of all plant discharges. A total of nine lake sampling points plus the discharge itself is needed for each outfall. As indicated in Figure 4.3.1, lake sampling at each discharge point is to be conducted in a concentric-radial manner. The radial angles are set at 45°, but the distance between the arcs (D) will be determined by the proximity of other plant discharge points. The distances will be set to insure no overlapping of plant discharges. A composite grab sample is to be obtained at each lake sampling point with samples taken at the surface, at one-third the total depth, and at two-thirds the total depth. Radial angles and distances are to be determined by a surveying transit set up on shore.

4. Sampling of lake bottom sediments near plant discharges. Lake bottom samples are to be collected at each of the nine sampling

FIGURE 4.3.1

ELFOULADH STEEL PLANT, TUNISIA
TYPICAL LAKE SAMPLING LOCATIONS
FOR A PLANT DISCHARGE



NOTES:
- Nine sample locations
- Transects A, B, C
- Distance between concentric arcs (D) to vary depending on proximity of other plant discharges.

points for each outfall and analyzed for specific water quality parameters. This information will be used to determine the deposition of suspended particles and contaminants near plant discharges.

5. Fish bioassays are to be conducted on each lake discharge. These tests entail adding native fish to various dilutions of wastewater with the fish survival rate recorded. Wastewaters both before and after various stages of proposed treatment will be examined. Results give a quantitative comparison of different treatment schemes.

4.3.1.2 Discharge Assessment Analytical Testing

The specific analytical tests to be carried out on both lake samples and sediment samples are to correspond to water quality parameters representative of the specific plant discharge. Refer to Table 4.3.1 for a list of representative parameters. Analysis of the sediment samples will require different pretreatment steps before standard water quality analysis can be conducted. The specific pretreatment step will vary with the parameter determined. Pretreatment usually involves either agitation in a low pH solution or a chemical digestion step. It is hoped that all analytical testing can be performed on site. This will serve to reduce the cost of analysis, plus results will be obtained more quickly than if a private laboratory was used.

4.3.2 Water/Wastewater Characterization and Treatability Studies

Before economically attractive and sound engineering solutions aimed at upgrading the existing water/wastewater treatment systems can be developed, a complete evaluation of the plant's water/wastewater flows and treatment processes must be conducted. Here, water refers to plant cooling waters, and wastewaters refer to flows which are too badly contaminated to be used in plant processes and must be treated prior to lake discharge.

TABLE 4.3.1
ELFOULADH STEEL PLANT, TUNISIA
ANALYTICAL TESTS REQUIRED FOR WATER/WASTEWATER
CHARACTERIZATION AND TREATABILITY STUDIES

Water Quality Parameter	Water and Wastewater Flows					
	Blast Furnace Scrubber Water	Pickling Liquor Wastewaters	Continuous Casting Spray Recirculating Water	Cooling Waters	Storm Runoff[1]	Sludges
Alkalinity	x	-	x	x	x	-
Ammonia Nitrogen	x	-	-	-	-	-
Nitrate Nitrogen	x	-	-	-	x	-
Total Cyanide	x	-	-	-	-	-
Free/Fixed Cyanide	x	-	-	-	-	-
Cyanide Amenable to Chlorination	x	-	-	-	-	-
Phenols	x	-	-	-	-	-
Fluoride	x	-	-	-	-	-
pH	x	x	-	x	x	x
Total Suspended Solids	x	x	x	x	x	x
Dissolved Iron	-	x	-	-	x	x
Oil & Grease	-	x	x	x	x	-
Chemical Oxygen Demand	x	x	-	x	x	-
Chlorine	x	-	-	-	-	-
Chloride	x	-	-	-	-	-
Total Solids	-	-	-	x	-	x
Total Dissolved Solids	x	x	-	x	x	x
Conductivity	x	x	-	x	x	x
Hardness	x	-	x	x	x	-
Phosphate (total)	-	-	-	x	x	-
Phosphate (ortho)	-	-	-	x	x	-
Sulfate	x	x	x	x	x	-
Lead	x	x	-	-	-	-
Zinc	x	x	x	-	-	-
Copper	x	x	-	-	-	-
Nickel	-	x	-	-	-	-
Chromium	-	x	-	-	-	-
Arsenic	-	x	-	-	-	-
Antimony	-	x	-	-	-	-

NOTE: x = indicates test to be done.

(1) Water quality parameters measured will depend upon the specific runoff areas. Those parameters indicated will be measured in all runoff samples.

It is difficult to give detailed specifics of the water/wastewater characterization and treatability studies mainly due to the fact that preliminary sampling and testing results dictate the subsequent tests to be conducted. For this reason, only a general discussion is given.

4.3.2.1 Study Specifics

Water/wastewater characterization and treatability studies are to be conducted on the following:

1. All process wastewater streams. To include blast furnace scrubber water, pickling operation wastewaters, continuous casting spray waters, plus any other wastewaters generated by the plant.

2. Storm runoff waters.

3. Cooling waters.

4. Sludges produced from water and wastewater treatment processes.

A water/wastewater characterization study and a water/wastewater treatability study are basically different in their concepts, but results from both are equally needed to develop sound engineering solutions to wastewater problems.

Water/Wastewater Characterization Study Outline

Water/wastewater characterization involves determination of flowrates and water quality of all water and wastewater streams within the plant. For those flows that receive treatment, samples both before and after treatment are analyzed. Specifics include:

1. Measuring flowrates and concurrent stream sampling. Flowrates are measured by various methods. These include the installation of portable weirs, ultrasonic flow measurement, estimates from pump

discharge pressures, and as a last resort, a bucket and stopwatch. Whenever possible, two methods are used to check results.

Sampling of the streams for water quality analysis is to be done either automatically on a 24-hour composite basis, or by grab sampling. The method usually depends upon the specific stream. The water quality parameters selected for analysis will vary depending upon the respective flow. Refer to Section 4.3.1.3 for the parameters to be determined in the different streams.

2. Conducting a plant water balance. This entails measuring flows in an attempt to balance the incoming plant waters with the plant discharge waters.

3. Evaluation of the plant's existing storm sewer system. Segregation of the entire plant area into contaminated and non-contaminated areas will be examined. Whether an area is determined to be contaminated or non-contaminated will depend upon its physical appearance along with water analysis results of runoff generated from the area. The possibility of collecting storm runoff for use within the plant is also be be looked at.

Water/Wastewater Treatability Study Outline

Water and wastewater treatability studies serve to examine the treatment capabilities of both existing and proposed treatment schemes. The studies can involve bench-scale or full-scale testing of treatment processes.

Bench-scale treatability studies entail simulating an existing or proposed treatment process on a laboratory scale and subsequently measuring the treatment efficiency. In laboratory-scale studies, only a one- or two-liter volume of water or wastewater is subjected to varying chemical additions, varying mixing intensities, varying mixing durations, varying pH, and varying solids settling times. The optimal treatment scheme and operating

conditions determined by bench-scale testing is examined on a full-scale basis, if it is possible without major process changes.

Full-scale treatability studies involve making minor operational changes to an existing treatment process and subsequently measuring the effect on treatment efficiency. Operational changes may include varying the chemical addition, enhancing mixing of the chemical and wastewater, changing the point of chemical addition, and reducing the wastewater flowrate. Usually, any changes are based on bench-scale (laboratory) testing results.

Advantages of laboratory-scale studies over full-scale studies are:

1. Laboratory-scale studies are more easily controllable. The effect on treatment of varying operating parameters can be examined with relative ease.

2. The cost of laboratory-scale studies is less than full-scale studies. Only a very small quantity of treatment chemicals is needed.

3. An estimate of sludge produced from treatment processes can be easily obtained.

4. The feasibility of proposed treatment processes can be quickly and easily simulated and evaluated.

The only main disadvantage of bench-scale studies is that unforeseen operational problems (e.g., automatic control of chemical addition) are not clearly evident.

4.3.2.2 Study Objectives

Results for both the water/wastewater characterization and treatability studies are to be used concurrently to develop economical engineering solutions which will:

1. Reduce the process wastewater flowrates requiring treatment. To be achieved by making appropriate process changes, decreasing the blowdown rate from recycled cooling water systems and examining water reuse. Lower flowrates will serve to reduce the required size of respective treatment processes along with decreasing usage of treatment chemicals.

2. Optimize efficiencies of existing treatment processes. Through economically attractive system modifications, the most optimal operating conditions of the treatment processes can be developed. These include mixing schemes, operating pH, chemical additions, and proper process equipment controls.

3. Determine which water/wastewater streams can be combined and treated. This will depend upon the nature of the waters, the degree of treatment required, and the plant locations where the flows are generated.

4. Provide adequate sludge handling and disposal. Study results will give an estimate of the sludge produced both from wastewater treatment processes and water treatment processes. The economic feasibility of sludge dewatering can be examined.

5. Aid in segregating the plant into contaminated and non-contaminated runoff areas. The water quality of the runoff from various parts of the plant will be measured along with the flows expected. Along with this will be an evaluation of the feasibility of storing and using storm runoff as plant makeup cooling water. Treatment to the required degree will also be examined.

6. Consider reuse of treated wastewaters as make-up waters for cooling systems. The degree of treatment required will depend upon the particular wastewater and the particular cooling water system.

4.3.2.3 Analytical Testing

This section gives the different analytical tests needed for comprehensive water/wastewater characterization and treatability studies.

Table 4.3.1 lists the specific tests required for both characterization and treatability studies of different water and wastewater flows. Only those water quality parameters that were measured in concentrations greater than 0.5 mg/L in comparable flows at various United States steel plants are indicated in the table. The number of tests required for each flow will vary depending upon preliminary monitoring study results. All water quality testing is to be done at the plant site. Section 4.3.3 lists the equipment needed to perform the required characterization and treatability studies.

4.3.3 Water Quality Monitoring Study Equipment List with Itemized Cost

This section gives the equipment (with cost) needed to conduct a complete water quality monitoring study at the ELFOULADH Steel Plant. The equipment specified is that which is needed to perform sampling, flow measurements, treatability studies, and water quality analysis. Once the monitoring study is complete, the equipment can still be used by the plant for in-house monitoring and control purposes.

Table 4.3.2 lists the major equipment (with cost) needed to perform sampling, flow measurements, and treatability studies. For an intensive water study, duplication of some equipment (e.g., flow recorders, samplers, etc.) is usually necessary, but this should be supplied by the firm conducting the study.

Table 4.3.3 lists the analytical equipment (with cost) needed to perform all the required water quality tests for the parameters listed in Table 4.3.1 except for the heavy metals lead, nickel, arsenic, and antimony. These analyses will have to be performed by a private laboratory if capabilities are not available at the plant. Disregard any equipment specified which is presently available at the plant.

TABLE 4.3.2

ELFOULADH STEEL PLANT, TUNISIA
WATER QUALITY MONITORING STUDY EQUIPMENT LIST
FOR FLOW MEASUREMENTS, SAMPLING, AND TREATABILITY STUDIES

Equipment Name	Quantity	Equipment Description	United States Cost
Automatic Sampler[1]	1	Isco Model 1680 composite and discrete sampler w/ batter option	$ 2,000
Recording Flowmeter[1]	1	Isco Model 1870 recording flowmeter	$ 3,000
Ultrasonic Flowmeter[1]	1	Portable ultrasonic flowmeter to measure flows in closed pipes.	$ 1,500
Six-Paddle Stirrer[1]	1	Aluminum frame stirrer illuminator base. For use in simulating treatment processes	$ 760
Settlometer[1]	1	Mallory direct reading settlometer for suspended solids settling studies	$ 80
Hydrolab[1]	1	Digital water quality measurement system for temperature, pH, dissolved oxygen, and conductivity	$ 4,500
Portable V-Notch Weirs[1]	1 set	Portable v-notch weirs to fit pipe diameter range from 0.2 meters to 1.07 meters	$ 600
Rain Gauge[1]	1	Universal recording rain gauge	$ 1,000
Water Sampler	1	Wildco water sampler to sample lake at various depths	$ 400
Core Sampler	1	Wildco Ballcheck deep water core sampler. Can sample lake bottom to depth of 60 meters	$ 700
Fluorescent Dyes	2 bottles	Red and yellow fluorescent dyes to be used in dye studies	$ 50
		TOTAL	$14,590

NOTE: Boat rental for approximately one week period is not included.

(1) See Appendix 5 for detailed information on equipment.

The water quality monitoring study equipment list given may be able to be narrowed down once a preliminary plant visit is conducted and the plant's analytical capabilities specifically examined.

TABLE 4.3.3
ELFOULADH STEEL PLANT, TUNISIA
WATER QUALITY MONITORING STUDY
ANALYTICAL EQUIPMENT LIST

Equipment Name	Quantity	Equipment Description	United States Cost
Water/Wastewater Analysis Kits[1] for:			
Alkalinity	2	150 tests per kit @ $36 each	$ 72
Chloride	2	150 tests per kit @ $63.50 each	127
Chlorine	2	150 tests per kit @ $43 each	86
Chromium (+6)	2	150 tests per kit @ $35.50 each	71
Chromium (total)	2	150 tests per kit @ 52 each	104
Copper	2	150 tests per kit @ $47 each	94
Hardness	2	150 tests per kit @ $50 each	100
Dissolved Iron	2	150 tests per kit @ $37.50 each	75
Ammonia Nitrogen	2	150 tests per kit @ $40 each	80
Nitrate Nitrogen	2	150 tests per kit @ $50 each	100
Phosphate (total)	2	75 tests per kit @ $46 each	92
Phosphate (ortho)	2	50 tests per kit @ $39 each	78
Sulfate	2	150 tests per kit @ $30.50 each	61
Zinc	2	100 tests per kit @ $60 each	120
Chemical Oxygen Demand	2	100 tests per kit @ $500 each (includes digestion rack)	1,000
Phenols	1 5 refill packs	30 tests per kit @ $40 each 30 per refill @ $17 each	40 85
pH Meter	1	Orion Specific-Ion Analog Meter	1,000
pH Electrode	2	Orion combination pH electrode @ $90 each	180
Fluoride Specific Ion Electrode	2	Orion fluoride electrode to be used with Orion specific-ion analog meter @ $425 each	950
Cyanide Analysis Equipment	2	Distillation apparatus @ $400 each	800
Total Suspended Solids and Total Dissolved Solids Analysis Equipment	2	Includes filtering flask funnel, and filters for 500 tests @ $200 each	400
Vacuum Pump	1	To be used for total suspended solids analysis	400
Spectrophotometer	1	B&L Spectronic 20 - to be used with water/wastewater analysis kits	900
Balance	1	Mettler PK-300 electronic top loading balance	3,800
Conductivity	1	Fisher portable conductivity meter	600
Drying Oven	1	Fisher gravity convection airflow drying oven (temperature range of 25°C to 200°C)	300
Oil & Grease Analysis Equipment	2	Includes equipment for freon extractable method - includes water bath, nitrogen gas source, and separatory funnels (@ $500 each)	1,000
Miscellaneous Laboratory Items		Includes magnetic stirrers, glassware, chemical reagents, pipettes, and desiccator - estimated cost	2,000
		TOTAL	$14,715

NOTE: Equipment provides for all required analyses except lead, nickel, arsenic, and antimony. These analyses will have to be provided for by the plant or a private laboratory.

(1) Cost includes reagents and glassware. Spectrophotometer needed.

4.3.4 Water Quality Monitoring Cost Estimate

The cost of the monitoring plan, described in the previous sections, is dependent on the information obtained as a result of a preliminary visit by several engineers, as recommended in Section 4.3 This survey would enable the engineers to prepare a detailed monitoring study which would serve as a firm cost basis.

The cost of the survey and monitoring plan preparation would be approximately $18,000 US. This does not include travel or living expenses.

EXHIBITS

PLANT SAFETY REGULATIONS

INDEX

EXHIBIT 3.5
PLANT SAFETY REGULATIONS
INDEX

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V. SAFETY AWARDS

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2. Steam Driven Reciprocating Pumps
3. Centrifugal Pumps
4. Air Compressor Operations

EXHIBIT 3.5.1

PROTECTIVE CLOTHING AND EQUIPMENT

1. EYE, HEAD, FOOT AND ARM PROTECTION

   a. Approved safety headwear issued by the Plant Safety Department shall be worn by all personnel while working in the Plant.

   b. Safety glasses are required to be worn in all areas of the plant at all times, except when inside the areas or situation listed: Guard Office, Clock Office, Service Building, Main Office, Plant Office, Labor Office, Maintenance Office, Engineering Building, and so on.

      Contact lenses shall not be worn in the plant.

      No tinted lenses of any kind shall be worn in the plant unless express permission is given by the Safety Department.

   c. Clothing which covers the upper part of the body must have sleeves that cover the arms to the wrists and shall be worn in that fashior Legs must be covered to the ankles.

   d. All new employees, after 30 days employment, shall wear safety toe shoes. Tennis shoes, or any shoe of similar porous nature are stictly prohibited in the plant. Cleats are also prohibited on the heels or soles of shoes worn in the plant.

   e. Appropriate clothing shall be worn suitable for the work being performed as directed by the supervisor.

   f. Do not wear loose coats, sweaters, flowing ties or clothing with loose or torn sleeves or torn trouser legs when working around machinery.

g. Greasy or oily clothing may easily catch fire. Clothing which may have absorbed acids is also dangerous to the body. Have work clothes laundered frequently.

h. Keep shoes in good repair. A good sole is protection against nails, sharp objects and falls.

i. Safety shoes should be worn by all employees to prevent toe injuries.

j. Visitors and employees of private contractors performing work within the plant are required to comply with the above rules with regard to wearing protective apparel.

k. When a supervisor orders an individual to wear a piece of safety equipment, the individual shall wear it, or subject himself to disciplinary action.

2. PROTECTIVE EQUIPMENT

a. Safety Belts shall be worn when it is necessary to work in an elevated or overhead position that is not protected by railings or platforms and/or exposed to noxious or toxic gases or where such work cannot be done safely from the use of ladders or scaffolds, or where catch platforms, or temporary floors are impractical.

Employees must be trained on the use of safety belts and harnesses so that they can automatically use same without requiring instructions.

Lifelines, safety belts and lanyards shall be used only for employee safeguarding. Any lifeline, safety belt or lanyard subjected to unsafe loading shall be tagged and immediately removed from service and discarded. Every safety belt and lifeline shall be properly stored, maintained and periodically inspected.

Safety nets shall be provided when workplaces are more than 25 feet above the ground or other surfaces where the use of ladders, scaffolds, catch platforms, temporary floors, safety lines, or safety belts is impractical.

b. Approved respiratory protection, as specified in the Plant Respiratory Protection Program, shall be worn when it is necessary to enter a tank, tank car, still or other closed vessel or when directed by their supervisor.

No employee shall wear a respirator until trained in its use and limitations as well as its proper fitting and maintenance.

Respirators are to be issued for one shift only and under no circumstances can a respirator be loaned to another employee for that shift or for a subsequent shift.

A "tool loan order" form showing date of issue, description of respirator, and your name shall be completed and presented to the storeroom keeper in charge of safety prior to your receiving a respirator. At the end of your shift, the "tool loan order" form will be returned to you after your respirator has been logged as being returned.

c. In addition to safety glasses, GOGGLES OR FACESHIELDS shall be worn as specified below:

(1) Goggles or faceshields shall be worn when taking samples that are corrosive, flammable, or hot.

(2) Full faceshields shall be worn when breaking steam, process or fuel lines. In addition, faceshields shall be worn when breaking any line in the Acid Plant.

(3) Goggles or faceshields as determined by the Supervisor, shall be required to be worn when working on plugged lines where

the line has been broken unless the Supervisor in charge has determined that they will not be needed.

(4) Except for posted aisleways, goggles shall be worn in the Acid and Caustic Plants.

(5) Goggles and/or faceshields shall be worn at the Acid and Base Barrel Docks as specified.

EXHIBITS 3.5.2 & 3.5.3

EXHIBIT 3.5.2

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT

SCHENECTADY, N. Y. 12305

Phone: (518) 385-4085 DIAL COMM: 8*235-4085

MATERIALS INFORMATION SERVICES

NO. 9

SULFURIC ACID, CONCENTRATED

REVISION B

Date October 1980

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: SULFURIC ACID, CONCENTRATED
OTHER DESIGNATIONS: Oil of Vitriol, Hydrogen Sulfate, H_2SO_4 GE Material D4A2, CAS #007 664 939
DESCRIPTION: Material consists of about 93-98% H_2SO_4 with water and traces of impurities.
MANUFACTURER: Available from many suppliers.

SECTION II. INGREDIENTS AND HAZARDS	%	HAZARD DATA
Hydrogen Sulfate (H_2SO_4) Water	93-98 Balance*	TLV 1 mg/m^3 for sulfuric acid† Human, mist inhal. TCLo 3 mg/m^3, 24 wk (Toxic Mouth Effects) Rat, Oral LD_{50} 2140 mg/kg

*Material is obtained by the reaction of SO_3 and water. Can contain low impurity levels, such as 0.02% max of iron as Fe. Properties vary with H_2SO_4 content.

†Current OSHA standard and ACGIH (1980) TLV. NIOSH has a 10-hr-TWA, 40 hr work week, of 1 mg/m^3.

SECTION III. PHYSICAL DATA

	93.19% H_2SO_4	98.33% H_2SO_4	100% H_2SO_4
Boiling point, 1 atm, deg C	ca 281	ca 338	ca 330 (dc)
Specific gravity (60/60 F)	1.8354	1.84	1.84
Deg. Baume	66	—	—
Volatiles, % at 340 C	ca 100	ca 100	ca 100
Melting point, deg C	ca -34	ca 3	10.4
Vapor press, mm Hg @ 100 F	<1	—	—

Water solubility: Completely miscible.
Appearance & Odor: Clear, colorless, hygroscopic oily liquid with no odor.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPER
None - nonflammable	N/A	N/A	N/A	N/A

Even though sulfuric acid is nonflammable, it is hazardous when present in a fire area. Small fires may be smothered with suitable dry chemical. Cool exterior of storage tanks of H_2SO_4 with water to avoid rupture if exposed to fire. Do not add water or other liquid to the acid! The acid, especially when diluted with water, can react with metals to liberate flammable hydrogen gas.
Sulfuric acid mists and vapors from a fire area are corrosive. (See Sect. V.)
Firefighters to wear self-contained breathing equipment and full protective clothing.

SECTION V. REACTIVITY DATA

Sulfuric acid is stable under normal conditions of use and storage. It does not undergo hazardous polymerization.
It is a strong mineral acid reacting with bases and metals. The concentrated acid is a strong oxidizing agent and can cause ignition of combustible materials on contact. The concentrated acid is also a dehydrating agent, picking up moisture readily from the air or other materials.
Reacts exothermically with water. (Acid should always be added slowly to water. Water added to acid can cause boiling and uncontrolled splashing of the acid.)
Sulfur oxides can result from decomposition and from oxidizing reactions of sulfuric acid.

GENERAL ELECTRIC

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EXHIBIT 3.5.3

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT

SCHENECTADY, N. Y.

MATERIALS INFORMATION SERVICES

NO. 30 A

HYDROCHLORIC ACID

Date October 1977

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: HYDROCHLORIC ACID
DESCRIPTION: This material is a water solution of hydrogen chloride gas.
OTHER DESIGNATIONS: Muriatic Acid, Concentrated Hydrochloric Acid, GE Material D4A3, CAS 007647010
MANUFACTURER: Available from many suppliers

SECTION II. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Hydrogen chloride (HCl)	<38	TLV 5 ppm (C)*
Impurities (depends on acid grade)	Traces	
Water	Balance	

*C denotes a ceiling concentration that should not be exceeded in the workplace

SECTION III. PHYSICAL DATA

	18°Be'	20°Be'	22°Be'	23°Be'
Weight % HCl	27.9	31.4	35.2	37.1
Boiling pt, 1 atm, deg F	208	182	144	123
Freezing point, deg F	-43.6	-63.4	-86.3	-101.2
Specific gravity, 60/60 F	1.142	1.160	1.179	1.189
Vapor pressure, 25 C, mm Hg	--	25	--	--

Materials are completely water soluble and nearly 100% volatile.
Appearance & Odor: Colorless to lt. yellow fuming liquid with a pungent, suffocating odor.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits in Air	LOWER	UPPER
N/A	N/A	N/A		

Extinguishing media: Select that suitable for surrounding fire.
This nonflammable material can react with many metals, such as iron, to produce flammable hydrogen gas. The acid can be neutralized with bases such as slaked lime or soda ash.
Use a water spray to cool fire exposed containers to prevent rupture.
Firefighters should use full protective clothing and self-contained breathing apparatus when this material is involved in a fire situation.

SECTION V. REACTIVITY DATA

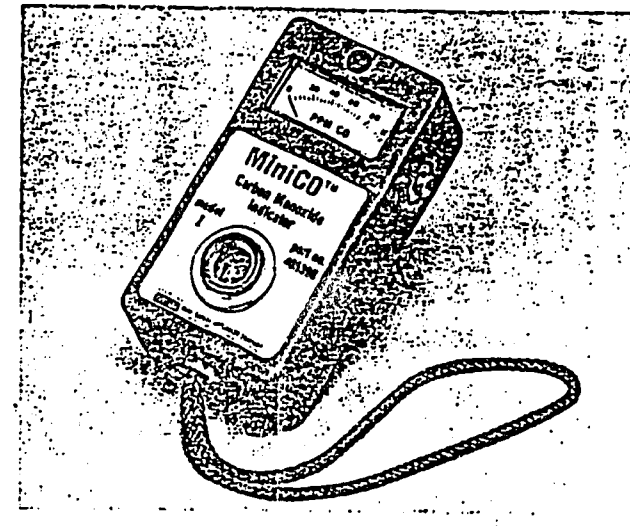
This material is stable when properly contained and handled. It is a strong mineral acid and is, thus, highly reactive with materials such as metals, metal oxides, hydroxides, amines, carbonates and other alkaline materials. It is highly corrosive to many materials.
It can liberate significant levels of HCl by vapor pressure at room temperature when concentrated and large amounts of HCl when heated.
Reaction with most metals will produce hydrogen gas.

EXHIBITS 3.5.4 & 3.5.5

Data Sheet
08-00-31

EXHIBIT 3.5.4

MiniCO™ Carbon Monoxide Indicator, Model I and Model II



Application

The MiniCO™ Indicator from MSA is a battery-powered, pocket-size device that provides an accurate, economical and easy means of measuring carbon monoxide concentrations in ambient air. It can be used wherever workers are exposed to conditions requiring continuing checks for CO, and can be carried in the pocket, on the belt, or simply hand-held. The user can obtain a meter readout showing parts per million of CO by simply pushing a button. The Model I has a measuring range of 0-100 ppm carbon monoxide-in-air; the Model II is calibrated for a range of 0-500 ppm CO-in-air.

Description

The MiniCO Indicator is a completely self-contained instrument that measures concentrations of carbon monoxide in air. It is engineered for easy, low-cost maintenance. Reliable solid-state circuits are packaged in a rugged, weather-resistant housing and the sensor assembly, which can last up to twelve months, is field replaceable. The battery power supply lasts up to twelve months under normal use or 160 hours of continuous operation. Battery powur level can be checked simply by pushing a button and observing an indicator light. Replacement batteries are commercially available. The unit can be field calibrated using an MSA® Calibration Kit.

Principle of operation

The sensor is an electrochemical polarographic cell. This cell electro-oxidizes CO to CO_2 in proportion to the partial pressure in the sample area and the resulting electrochemical signal is amplified and temperature compensated to drive the meter. Samples are introduced to the sensor by diffusion through a gas porous tetrafluoroethylene membrane.

ROBERTSHAW 5-MINUTE AIR CAPSULE

A clear advantage over other escape devices.

REQUIRES NO SPECIAL INVENTORY OF SPARE PARTS FOR RECHARGING

Air Capsule was designed for human beings. You'll see what we mean when you compare it to the others.

Take the gas mask, for example. It clings to your face and just a smile might loosen its air seal. And some models have nose and mouthpieces that can muzzle you, so it's difficult to make yourself clearly understood in an emergency. Besides, a gas mask is only safe if the atmosphere contains enough oxygen. And unlike Air Capsule, a gas mask never considers anyone wearing a beard or glasses.

On the other end of the spectrum, you have elaborate survival systems complete with bulky and heavy cylinders and regulators. Gear that appears more suitable for an astronaut or diver—not for a human being trying to escape from danger.

Air Capsule isn't anything like that. It fills the existing escape device gap. With a hood that offers all-around visibility, nonconfining protection and a continuous air flow that keeps out any hazardous atmosphere—no matter how toxic, our constant flow regulator gives you five minutes of air regardless of how fast or deeply you breathe.

Equally important, our compact, low-profile Air Capsule weighs only 4½ pounds and can be donned in less than 10 seconds. This way, you can get a head start in your fight for survival. It's simply the must natural escape device around. That alone is a clear improvement over the others.

The Air Capsule reservoir is warranted to retain its air supply for 3 years. If used, the Air Capsule can be recharged and used again.

Robertshaw Control Company

EXHIBIT 3.5.5

EXHIBIT 3.5.6

EXHIBIT 3.5.6

KOPPERS

Protective Coatings

TECHNICAL DATA SHEET

TYPE OF COATING
COAL TAR

Product: **BITUMASTIC SUPER SERVICE BLACK**

DESCRIPTION: A self-priming, heavy-duty, cold-applied, water resistant coating made from pitch derived from suitable tars, selected solvents, mineral fillers and special additives.

USE: FOR INDUSTRIAL USE ONLY. NOT INTENDED FOR USE IN THE HOME.

One of its outstanding features is providing a thick film that will protect metal and concrete from severe chemical fumes and corrosive vapors. It has proven especially effective in the sewage industry by protecting metal and concrete against the deteriorating effects of raw and industrial waste materials and hydrogen sulfide gas. It can be used on all metal and concrete surfaces which will be buried or immersed.

When exposed to sunlight and effects of weathering, the coating should be aged approximately 2 to 4 weeks, then topcoated with Bituplastic No. 28 or Bituplastic No. 33. This minimizes weathering effects that result in alligatoring or cracking of coal tar films.

Do not use for the interior of tanks, containers or pipelines designed for containing potable water.

TECHNICAL DATA:

Number of coats:	Two, minimum
Volume solids:	68%
Theoretical coverage:	1,090 mil sq. ft./gal.
Coverage to achieve minimum dry film thickness:	60 to 70 sq. ft./gal./coat on smooth metal surfaces. (Allows for approximate 20% application loss.) Concrete surfaces, first coat, 50 to 60 sq. ft./gal./coat. (Includes 20% application loss.) Coverage will depend on surface profile and porosity.
Film build ratio:	
Minimum dry film required per coat:	12 to 14 mils
Wet film required per coat:	18 to 21 mils
Drying time at 70°F. and 50% relative humidity:	
To touch:	6 to 12 hours
Between coats:	24 to 48 hours
Prior to submerging:	14 days after final coat is applied

Koppers Company, Inc., Pittsburgh, Pennsylvania 15219

EXHIBIT 3.5.7

EXHIBIT 3.5.7

DESIGN OF LOCAL EXHAUST SYSTEMS FOR OPEN TANKS

Open-Surface Tanks

Open-surface tanks may be controlled by canopy hoods or by slot hoods, as illustrated in Figure 10. The latter are more commonly employed. The ventilation rates required for open-surface tanks may be taken from Table 4, which is a modification of the American Standards Association code Z 9.1. These values should be considered as minimum under conditions where no significant drafts will interfere with the operation of the hood. When slot hoods are employed the usual practice is to provide a slot along each long side of the tank. The slots are designed for a velocity of 2,000 fpm through the slot face at the required ventilation rate. For a tank with two parallel slot hoods, the ventilation rate required and the slot width b_s may be taken directly from Figure 11, which graphs the American Standards Association code Z 9.1.

Table 4. VENTILATION RATES FOR OPEN-SURFACE TANKS
(American Air Filter Company, Inc., 1964)

Process	Minimum ventilation rate, cfm per ft² of hood opening				Minimum ventilation rate,[a] cfm per ft² of tank area. Lateral exhaust $W/L = \frac{\text{tank width}}{\text{tank length}}$ ratio					
	Enclosing hood		Canopy hood		W/L 00 to 0.24		W/L 0.25 to 0.49		W/L 0.50 to 1.0	
	One open side	Two open sides	Three open sides	Four open sides	A	B	A	B	A	B
Plating										
Chromium (chromic acid mist)	75	100	125	175	125	175	150	200	175	225
Arsenic (arsine)	65	90	100	150	90	130	110	150	130	175
Hydrogen cyanide	75	100	125	175	125	175	150	200	175	225
Cadmium	75	100	125	175	125	175	150	200	175	225
Anodizing	75	100	125	175	125	175	150	200	175	225
Metal cleaning (pickling)										
Cold acid	65	90	100	150	90	130	110	150	130	175
Hot acid	75	100	125	175	125	175	150	200	175	225
Nitric and sulfuric acids	75	100	125	175	125	175	150	200	175	225
Nitric and hydrofluoric acids	75	100	125	175	125	175	150	200	175	225
Metal cleaning (degreasing)										
Trichloroethylene	75	100	125	175	125	175	150	200	175	225
Ethylene dichloride	75	100	125	175	125	175	150	200	175	225
Carbon tetrachloride	75	100	125	175	125	175	150	200	175	225
Metal cleaning (caustic or electrolytic)										
Not boiling	65	90	100	150	90	130	110	150	130	175
Boiling	75	100	125	175	125	175	150	200	175	225
Bright dip (nitric acid)	75	100	125	175	125	175	150	200	175	225
Stripping										
Concentrated nitric acid	75	100	125	175	125	175	150	200	175	225
Concentrated nitric and sulfuric acids	75	100	125	175	125	175	150	200	175	225
Salt baths (molten salt)	50	75	75	125	60	90	75	100	90	112
Salt solution (Parkerise, Bonderine, etc)										
Not boiling	90	90	100	150	90	130	110	150	130	175
Boiling	75	100	125	175	125	175	150	200	175	225
Hot water (if vent. desired)										
Not boiling	50	75	75	125	60	90	75	100	90	112
Boiling	75	100	125	175	125	175	150	200	175	225

[a]Column A refers to tank with hood along one side or two parallel sides when one hood is against a wall or a baffle running length of tank and as high as tank is wide; also to tanks with exhaust manifold along center line with W/2 becoming tank width in W/L ratio.

Column B refers to freestanding tank with hood along one side or two parallel sides.

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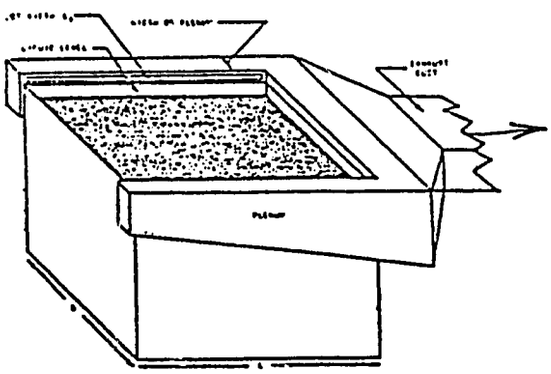

Figure 10. Slot hood for control of emissions from open-surface tanks (Adapted from Industrial Ventilation, 1960).

Neither the code nor Figure 11 makes allowance for drafts. The use of baffles is strongly recommended wherever possible to minimize the effect of drafts. If baffles cannot be used or are not sufficiently effective, the ventilation rate must be increased. The slot width is also increased to hold the slot face velocity in the range of 1,800 to 2,000 fpm.

The use of Figure 11 is illustrated in the following problem:

Example 3

Given:

A chrome plating tank, 2 feet wide by 3 feet long, to be controlled by parallel slot hoods along each of the 3-foot-long sides.

Problem:

Determine the total exhaust rate required and the slot width.

Solution:

From Figure 11, the ventilation rate required is 390 cfm per foot of tank length.

$$V_t = 390 \times 3 = 1,170 \text{ cfm}$$

From Figure 11, the slot width is $1\frac{1}{8}$ inches.

If a slot hood is used on only one side of a tank to capture emissions, and the opposite side of the tank is bounded by a vertical wall, Figure 11 can be used by assuming the tank to be half of a tank twice as wide having slot hoods on both sides. This procedure is illustrated below.

Example 4

Given:

The same tank as in Example 3, but a slot hood is to be installed along one side only. The other side is flush with a vertical wall.

Problem:

Determine the total exhaust rate and slot width required.

Solution:

The ventilation rate in cfm per foot of tank length is taken as half the rate for a tank twice as wide from Figure 11. Use width of 4 feet.

$$\frac{V_t}{L} = \frac{880}{2} = 440 \text{ cfm per foot}$$

Total exhaust volume required

$$V_t = 440 \times 3 = 1,320 \text{ cfm}$$

Slot width is read directly from Figure 11 for twice the width b_s = 2-5/8 inches.

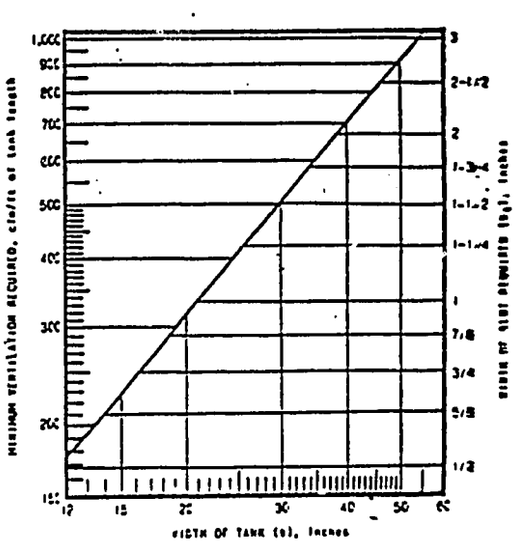

Figure 11. Minimum ventilation rates required for tanks.

APPENDIX 1

CRSTER AIR QUALITY DISPERSION MODEL

```
                    CRSTER (VERSION 80337)
                    AN AIR QUALITY DISPERSION MODEL IN
                    SECTION 2. GUIDELINE MODELS (1978)
                    IN UNAMAP (VERSION 4) DEC 80
                    SOURCE: FILE  6 ON UNAMAP MAGNETIC TAPE FROM NTIS.

PLANT NAME: CRSTER SIMULATION RUN     POLLUTANT:  TSP      EMISSION UNITS: GM/SEC    AIR QUALITY UNITS: GM/M**3

            MET FILE     REQUESTED
           STN NO. YR   STN NO. YR
 SURFACE    13737  74    13737  74
 UPPER AIR  13880  74    13880  74
PLANT LOCATION: RURAL
ANEMOMETER HEIGHT IS  7.0 METERS
WIND PROFILE EXPONENTS ARE:   0.100,  0.150,  0.200,  0.250,  0.300,  0.300,
NO TAPE OUTPUT
MET DATA WILL NOT BE PRINTED

DAY-- 1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 0

* * * * * * * * * * * * * * * * * * * * * * N O T E * * * * * * * * * * * * * * * * * * * *

        ALL TABLES, INCLUDING SOURCE CONTRIBUTION, THAT CONTAIN "ANNUAL" IN THE HEADING ARE BASED ONLY ON THOSE DAYS

        MARKED BY "1" IN THE ABOVE TABLE
```

RING DISTANCES(KM)= 0.53 0.69 0.90 1.23 1.60

PLANT ELEVATION (FEET ABOVE SEA LEVEL)-- 0.0

RECEPTOR ELEVATIONS (FEET ABOVE SEA LEVEL)

DIRECTION	RING#1	RING#2	RING#3	RING#4	RING#5
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0

PLANT ELEVATION (METERS ABOVE SEA LEVEL)-- 0.0

RECEPTOR ELEVATIONS (METERS ABOVE SEA LEVEL)

RING#1	RING#2	RING#3	RING#4	RING#5
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0

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STACK 1 1--STACK 1

STACK	MONTH	EMISSION RATE (GMS/SEC)	HEIGHT (METERS)	DIAMETER (METERS)	EXIT VELOCITY (M/SEC)	TEMP (DEG.K)	VOLUMETRIC FLOW (M**3/SEC)
1	ALL	5.8500	45.72	1.87	11.75	350.00	32.27

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PLANT NAME: CHSTEN SIMULATION NUM POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

			MAX HOURLY			MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
1	8.505	2.345526E-05	6	0.90	10	2.757677E-06	20	1.23
2	3.635	1.279960E-05	24	1.60	15	3.520850E-06	20	1.60
3	6.442	1.275154E-05	20	1.60	1	1.979416E-06	18	1.60
4	3.851	1.286207E-05	19	1.60	16	3.339788E-06	19	1.60
5	4.092	1.297364E-05	19	1.60	14	3.170262E-06	22	1.60
6	10.069	1.134172E-05	6	1.60	10	1.126442E-06	5	1.60
7	5.540	1.327126E-05	31	1.60	9	1.553968E-06	18	1.60
8	9.938	2.024005E-05	20	0.90	13	2.036537E-06	23	1.60
9	7.188	1.330792E-05	24	1.60	22	1.851418E-06	7	1.60
10	7.334	1.360270E-05	3	1.60	24	1.854644E-06	3	1.60
11	4.826	1.445702E-05	3	1.60	1	2.995470E-06	3	1.23
12	4.130	1.259410E-05	18	1.60	12	3.049665E-06	18	1.60
13	3.845	1.167295E-05	19	1.60	13	3.035546E-06	19	1.60
14	11.278	1.961744E-05	4	1.60	11	1.739413E-06	6	1.60
15	2.530	1.306230E-05	8	1.60	24	5.163271E-06	6	1.60
16	4.340	2.086440E-05	7	0.90	9	4.807076E-06	7	1.23
17	4.912	1.847102E-05	27	1.60	8	3.760464E-06	24	1.60
18	3.720	1.272840E-05	24	1.60	13	3.421391E-06	24	1.60
19	7.816	1.452772E-05	7	1.60	14	1.858713E-06	5	1.60
20	6.839	1.333761E-05	22	1.60	9	1.950179E-06	20	1.60
21	13.111	1.495648E-05	36	1.60	10	1.140773E-06	4	1.23
22	11.632	2.135172E-05	36	0.90	14	1.835596E-06	36	1.23
23	6.482	1.400020E-05	5	1.23	15	2.159826E-06	5	1.23
24	2.893	1.296702E-05	19	1.60	13	4.481664E-06	20	1.60
25	3.407	1.333761E-05	20	1.60	16	3.915173E-06	20	1.60
26	7.834	1.195833E-05	1	1.60	24	1.526469E-06	1	1.60
27	6.463	1.396360E-05	6	1.60	18	2.160580E-06	4	1.23
28	1.768	1.401189E-05	4	1.60	8	3.718842E-06	3	1.60
29	12.678	2.244536E-05	18	0.90	10	1.770487E-06	21	1.60
30	15.619	1.421354E-05	22	1.60	14	9.100023E-07	14	1.50
31	5.140	1.344465E-05	6	1.60	18	2.623464E-06	5	1.60
32	8.507	2.200313E-05	27	0.69	12	2.586499E-06	28	0.90
33	3.428	1.403351E-05	21	1.60	22	4.093657E-06	5	1.60
34	3.535	1.333513E-05	21	1.60	7	3.772449E-06	19	1.60
35	3.432	1.083322E-05	14	1.60	18	3.156544E-06	17	1.23
36	3.905	1.138677E-05	15	1.60	5	2.916016E-06	15	1.60
37	8.195	1.647207E-05	36	0.90	9	2.009958E-06	1	1.23
38	7.819	1.459516E-05	11	1.60	14	1.866695E-06	7	1.60
39	5.514	1.187903E-05	14	1.60	22	2.154379E-06	22	1.23
40	8.568	1.932433E-05	18	0.90	13	2.255344E-06	17	1.23
41	10.240	2.101339E-05	21	0.69	13	2.052074E-06	23	1.60
42	7.887	1.225526E-05	15	1.60	19	1.553771E-06	15	1.60
43	12.068	1.826778E-05	8	0.90	16	1.513735E-06	6	1.60
44	5.244	1.345216E-05	5	1.60	9	2.565129E-06	5	1.60
45	12.858	1.419445E-05	9	1.60	7	1.104225E-06	24	1.60
46	3.482	1.268946E-05	24	1.60	23	3.644359E-06	21	1.23
47	4.632	1.298791E-05	21	1.60	8	2.803896E-06	22	1.60
48	4.305	1.336994E-05	16	1.60	17	3.105800E-06	14	1.23
49	9.790	2.185803E-05	19	0.69	14	2.486833E-06	19	1.23

PLANT NAME: CHSTEN SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

		MAX HOURLY				MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
50	5.330	1.410886E-05	34	1.60	11	2.647296E-06	33	1.60
51	6.718	1.302329E-05	9	1.60	4	1.938693E-06	13	1.23
52	8.566	2.329253E-05	24	0.69	11	2.719136E-06	24	0.69
53	7.839	1.289474E-05	35	1.60	12	1.645002E-06	5	1.23
54	4.676	1.245710E-05	8	1.60	11	2.664053E-06	9	1.23
55	13.522	2.195578E-05	23	0.90	11	1.623657E-06	30	0.90
56	4.059	1.259082E-05	15	1.60	21	3.101981E-06	14	1.60
57	5.381	1.96[illegible]89E-05	17	0.90	16	3.643249E-06	16	1.23
58	13.210	2.782[illegible]5E-05	19	0.69	12	1.727702E-06	23	0.90
59	2.868	1.316513E-05	3	1.60	20	4.589690E-06	4	1.23
60	13.518	1.359842E-05	24	1.60	17	1.005961E-06	5	1.23
61	7.616	2.036778E-05	5	0.90	10	2.674325E-06	5	1.23
62	6.274	2.151719E-05	4	0.90	8	3.429754E-06	4	0.90
63	1.148	1.320524E-05	3	1.23	11	4.194305E-06	4	1.23
64	7.429	2.325111E-05	23	1.60	17	3.129986E-06	5	1.23
65	6.404	1.424955E-05	30	1.60	16	2.224951E-06	30	1.60
66	9.000	1.800264E-05	9	0.69	11	2.000268E-06	9	1.23
67	10.703	2.737341E-05	26	0.69	17	2.557576E-06	23	1.23
68	8.776	1.386403E-05	20	1.60	15	1.579731E-06	19	1.60
69	5.673	1.409690E-05	20	1.60	15	2.484861E-06	21	1.60
70	5.395	1.254290E-05	26	1.60	17	2.324821E-06	26	1.60
71	2.736	1.311805E-05	23	1.60	4	4.795100E-06	22	1.60
72	4.855	1.235088E-05	14	1.60	24	2.543989E-06	17	1.60
73	9.812	1.837228E-05	17	0.90	12	1.872402E-06	17	1.23
74	10.195	2.368845E-05	7	0.69	11	2.323478E-06	3	1.23
75	8.050	1.375292E-05	13	1.60	18	1.708465E-06	2	1.60
76	5.881	1.281118E-05	14	1.60	2	2.178218E-06	12	1.23
77	7.076	1.361432E-05	18	1.60	12	1.923916E-06	12	1.23
78	5.140	1.305895E-05	7	1.60	17	2.540640E-06	5	1.60
79	3.795	1.284137E-05	22	1.60	20	3.383774E-06	23	1.60
80	9.424	1.303031E-05	36	1.60	7	1.382723E-06	36	1.60
81	4.879	2.184258E-05	25	0.90	16	3.175460E-06	19	1.23
82	7.269	1.984971E-05	22	0.90	10	2.730830E-06	22	1.23
83	8.559	1.955986E-05	8	0.69	12	2.285429E-06	8	1.23
84	4.079	1.223121E-05	20	1.60	21	2.998269E-06	21	1.60
85	6.566	2.240438E-05	24	0.69	10	3.472980E-06	5	1.23
86	11.190	2.152104E-05	34	0.90	16	1.923241E-06	24	0.90
87	14.079	2.494771E-05	14	0.69	11	1.771989E-06	13	0.69
88	4.062	1.359842E-05	25	1.60	13	3.347556E-06	25	1.60
89	6.056	1.328492E-05	6	1.60	24	2.193526E-06	11	1.60
90	4.237	1.285402E-05	9	1.60	12	3.033737E-06	11	1.23
91	14.653	2.006058E-05	33	0.90	10	1.369087E-06	35	1.23
92	5.136	1.355150E-05	8	1.23	17	2.638584E-06	4	1.23
93	7.607	2.420834E-05	2	0.90	13	3.182570E-06	1	1.23
94	5.668	1.415850E-05	2	1.60	23	2.497755E-06	4	1.23
95	7.090	1.554243E-05	14	1.60	16	2.192246E-06	4	1.23
96	3.013	1.320044E-05	12	1.60	8	4.330716E-06	10	1.60
97	5.524	2.462083E-05	5	0.90	11	4.456760E-06	4	0.90
98	4.592	1.452098E-05	34	1.60	20	3.162425E-06	3	1.60
99	6.314	1.185568E-05	16	1.60	14	2.194316E-06	17	1.60

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PLANT NAME: CHSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

		MAX HOURLY				MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
100	5.821	1.341607E-05	17	0.69	12	2.303889E-06	15	1.60
101	7.213	2.196546E-05	22	0.53	12	3.045129E-06	24	0.90
102	5.854	1.406039E-05	4	1.60	8	2.401937E-06	4	1.60
103	3.804	1.498668E-05	6	1.60	21	3.939271E-06	5	1.60
104	5.282	1.870662E-05	2	0.69	12	3.541347E-06	6	1.60
105	8.417	2.064183E-05	11	0.69	12	2.452304E-06	7	1.23
106	12.243	2.408307E-05	23	0.53	13	1.967063E-06	24	0.90
107	8.579	2.440114E-05	23	0.53	12	2.844428E-06	23	0.69
108	13.100	2.475369E-05	22	1.23	17	1.889607E-06	23	0.90
109	11.293	2.576807E-05	13	0.53	11	2.281722E-06	23	1.23
110	9.541	2.712785E-05	27	0.53	13	2.843289E-06	23	0.69
111	6.909	3.248794E-05	6	0.53	13	4.702527E-06	6	0.53
112	5.335	1.759941E-05	6	0.69	11	3.299063E-06	6	1.23
113	11.617	2.126332E-05	8	0.69	13	1.830430E-06	10	1.23
114	6.937	1.444175E-05	19	1.60	6	2.081866E-06	20	1.60
115	7.326	1.812485E-05	20	0.69	11	2.474205E-06	20	1.23
116	6.504	2.207005E-05	14	0.69	15	3.393309E-06	14	0.90
117	4.746	2.540720E-05	29	0.53	13	5.353384E-06	27	0.69
118	8.402	2.476444E-05	4	0.53	13	3.185385E-06	4	0.90
119	12.166	3.165625E-05	1	0.53	14	2.601970E-06	5	1.60
120	9.208	2.967316E-05	18	0.69	9	3.222637E-06	24	0.53
121	8.529	2.281317E-05	20	0.69	11	2.674795E-06	19	1.23
122	7.919	2.090373E-05	24	0.90	11	2.639853E-06	25	1.23
123	10.742	1.999300E-05	10	0.69	14	1.961140E-06	9	1.23
124	8.692	2.389548E-05	20	0.90	17	2.749318E-06	23	1.23
125	3.813	1.398724E-05	25	1.60	17	3.668152E-06	27	1.60
126	9.922	2.743298E-05	6	0.69	14	2.764757E-06	6	0.69
127	7.204	2.325447E-05	22	0.69	14	3.227911E-06	23	1.23
128	7.055	2.306661E-05	31	0.53	11	3.269693E-06	31	0.69
129	12.971	2.314409E-05	36	0.90	17	1.784284E-06	36	0.90
130	23.267	2.932810E-05	9	0.69	14	1.260509E-06	25	0.90
131	6.375	2.121976E-05	25	0.90	7	3.328405E-06	25	1.60
132	5.643	1.422517E-05	4	1.60	5	2.520818E-06	4	1.23
133	7.136	2.636760E-05	23	0.53	14	3.694799E-06	23	0.69
134	8.305	2.331311E-05	3	0.69	14	2.807280E-06	1	1.23
135	5.623	1.998849E-05	3	0.69	12	3.537139E-06	5	1.23
136	7.394	2.816713E-05	5	0.53	11	3.809467E-06	6	1.23
137	7.707	2.487875E-05	7	0.69	10	3.227910E-06	7	0.90
138	14.284	2.280766E-05	11	0.90	8	1.596721E-06	19	0.69
139	5.784	2.709299E-05	24	0.53	10	4.684525E-06	25	1.23
140	6.448	2.307710E-05	25	0.90	10	3.556891E-06	24	0.90
141	10.357	2.611199E-05	18	0.69	9	2.521261E-06	27	0.90
142	3.703	1.725955E-05	5	0.69	13	4.660861E-06	5	1.23
143	5.170	1.612131E-05	6	1.60	16	3.118393E-06	5	1.23
144	7.644	2.985499E-05	36	0.69	10	1.903669E-06	4	0.90
145	9.611	2.775685E-05	21	0.53	11	2.888092E-06	22	0.90
146	11.344	2.578807E-05	24	0.53	12	2.271570E-06	20	1.60
147	8.288	1.409247E-05	4	1.60	24	1.700283E-06	24	1.23
148	12.570	2.576807E-05	11	0.53	14	2.050029E-06	11	0.53
149	1.821	1.486157E-05	36	1.60	2	3.889842E-06	5	1.23

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PLANT NAME: CHSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

		MAX HOURLY				MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
150	14.086	2.541855E-05	7	0.90	11	1.804563E-06	7	1.23
151	11.031	2.775485E-05	23	0.53	12	2.516264E-06	21	1.23
152	6.437	2.460334E-05	13	0.69	14	3.822154E-06	13	0.90
153	12.090	2.317782E-05	2	0.90	14	1.917183E-06	1	1.60
154	5.981	1.487523E-05	26	1.60	10	2.486896E-06	18	1.60
155	8.997	2.635176E-05	23	0.53	11	2.929100E-06	24	0.69
156	10.331	2.410473E-05	24	0.53	11	2.333295E-06	27	1.23
157	5.279	2.171210E-05	23	0.69	13	4.112808E-06	24	1.23
158	3.652	1.348185E-05	19	1.23	18	3.691512E-06	23	1.23
159	2.802	1.396537E-05	21	1.60	1	4.983807E-06	18	1.23
160	10.325	3.425820E-05	23	0.53	12	3.317964E-06	23	0.53
161	7.190	2.538079E-05	5	0.69	12	3.530146E-06	6	0.69
162	7.209	2.874115E-05	22	0.53	16	3.986629E-06	23	0.69
163	11.331	3.015988E-05	15	0.90	11	2.661694E-06	15	0.69
164	8.654	2.232530E-05	27	0.69	13	2.579635E-06	23	1.23
165	10.292	2.703363E-05	28	0.53	11	2.626550E-06	27	1.60
166	6.869	2.964183E-05	30	0.53	13	4.315030E-06	30	0.53
167	8.451	2.318557E-05	30	0.69	15	2.743586E-06	31	0.69
168	7.027	2.325111E-05	7	1.60	5	3.308917E-06	21	1.23
169	8.940	2.763873E-05	11	0.69	8	3.091717E-06	10	0.69
170	9.105	2.921804E-05	9	0.53	11	3.209116E-06	36	0.69
171	8.800	2.357173E-05	4	0.69	12	2.678608E-06	5	0.90
172	3.188	1.893150E-05	5	0.90	7	5.938369E-06	5	0.90
173	13.450	3.535414E-05	15	0.53	12	2.628594E-06	15	0.53
174	11.932	3.104603E-05	10	0.90	11	2.605290E-06	9	0.69
175	4.157	1.486379E-05	24	1.60	21	3.575651E-06	18	1.23
176	8.474	2.461663E-05	23	0.90	17	2.905009E-06	23	1.23
177	12.514	2.436526E-05	24	0.90	11	1.947068E-06	24	0.90
178	6.848	1.540383E-05	27	1.60	7	2.249513E-06	25	1.23
179	7.787	1.338608E-05	9	1.60	16	1.718996E-06	11	1.60
180	7.545	2.347838E-05	25	0.90	18	3.111779E-06	22	1.23
181	6.219	2.424095E-05	6	0.90	8	3.897969E-06	4	1.23
182	6.040	2.334055E-05	6	0.69	14	3.864640E-06	5	1.23
183	13.350	3.535360E-05	23	0.53	14	2.648289E-06	23	0.53
184	7.717	2.523682E-05	8	0.69	9	3.270296E-06	5	1.60
185	9.134	2.560008E-05	5	0.69	10	2.802457E-06	5	0.90
186	8.682	2.283534E-05	4	0.69	14	2.630205E-06	6	0.90
187	4.625	2.331785E-05	5	0.69	13	5.042033E-06	4	1.60
188	19.131	2.772229E-05	19	0.53	14	1.449094E-06	20	0.69
189	7.802	3.044234E-05	21	0.53	11	3.901765E-06	22	0.53
190	11.565	3.236591E-05	5	0.69	15	2.798552E-06	9	0.90
191	11.411	3.336352E-05	10	0.69	16	2.923817E-06	13	0.53
192	8.967	2.274527E-05	24	0.69	13	2.536549E-06	23	1.23
193	8.570	2.732117E-05	18	0.53	12	3.187934E-06	20	0.90
194	14.482	3.920971E-05	24	0.53	14	2.707443E-06	13	0.69
195	7.956	3.070238E-05	14	0.53	12	3.858851E-06	9	0.69
196	10.389	3.021962E-05	4	0.53	11	2.904849E-06	10	0.90
197	8.017	2.454721E-05	20	0.69	13	3.062017E-06	20	1.23
198	4.044	2.833401E-05	21	0.53	16	7.006590E-06	22	0.69
199	9.411	2.613757E-05	4	0.90	11	2.777286E-06	2	0.90

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PLANT NAME: CRSTEM SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

			MAX HOURLY				MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
200	7.088	1.720385E-05	6	1.60	21	2.427111E-06	9	1.23
201	6.091	2.176297E-05	19	0.69	11	3.572725E-06	20	1.23
202	11.273	3.000309E-05	26	0.69	11	2.661551E-06	27	0.69
203	9.025	2.891695E-05	23	0.53	11	3.204016E-06	23	0.69
204	8.456	2.542091E-05	23	0.53	11	3.006240E-06	23	0.90
205	19.246	2.538139E-05	6	0.90	13	1.316037E-06	3	1.23
206	8.513	2.267906E-05	20	0.90	11	2.664179E-06	23	0.90
207	7.704	1.655920E-05	33	1.60	11	2.149352E-06	34	1.60
208	12.415	1.596807E-05	35	1.60	17	1.286205E-06	30	1.60
209	10.549	2.899944E-05	25	0.53	16	2.749056E-06	21	1.23
210	11.362	3.024664E-05	25	0.53	14	2.663846E-06	24	0.53
211	9.672	2.818972E-05	3	1.23	11	2.914702E-06	3	1.23
212	15.065	3.492936E-05	15	0.53	13	2.318607E-06	5	0.90
213	14.386	1.554513E-05	1	1.60	1	1.080554E-06	36	1.60
214	8.191	2.559549E-05	3	0.90	11	3.124895E-06	2	1.23
215	6.616	2.090025E-05	3	0.69	13	3.159183E-06	1	1.60
216	7.075	1.502515E-05	5	1.60	24	2.123725E-06	2	1.60
217	11.813	2.451832E-05	36	0.90	12	2.075614E-06	5	1.60
218	7.535	1.390273E-05	24	1.60	18	1.845196E-06	25	1.60
219	15.151	1.614311E-05	7	1.60	12	1.065461E-06	1	1.23
220	11.018	2.786214E-05	32	0.69	13	2.528830E-06	32	0.90
221	8.034	2.220980E-05	3	1.60	9	2.764499E-06	36	1.60
222	5.462	2.026386E-05	20	0.69	11	3.710209E-06	23	1.23
223	4.382	1.866623E-05	22	0.69	11	2.924618E-06	21	1.23
224	6.879	2.929042E-05	23	0.69	14	4.258217E-06	23	0.69
225	15.956	2.901725E-05	11	0.69	13	1.818560E-06	11	0.69
226	5.974	2.037213E-05	4	0.53	13	4.747457E-06	4	0.69
227	12.798	2.989839E-05	23	0.53	13	2.336204E-06	23	0.53
228	12.542	3.035357E-05	28	0.53	11	2.420082E-05	36	1.23
229	8.990	2.511698E-05	4	0.53	13	2.793980E-06	3	1.60
230	5.003	2.948349E-05	22	0.53	14	5.972878E-06	20	0.69
231	5.551	1.950713E-05	31	0.69	11	3.513910E-06	24	1.60
232	4.224	2.156836E-05	22	0.69	11	5.106457E-06	24	1.23
233	2.251	1.535302E-05	25	1.60	24	6.820055E-06	23	1.23
234	15.494	2.710205E-05	23	0.90	11	1.749230E-06	33	1.60
235	11.357	2.167298E-05	36	1.23	9	1.908374E-06	1	1.60
236	12.121	3.054227E-05	6	0.53	13	2.519725E-06	7	0.53
237	11.120	2.900027E-05	10	0.69	10	2.607830E-06	10	0.90
238	13.679	2.673479E-05	29	0.53	13	1.954388E-06	29	0.69
239	11.375	3.426680E-05	34	0.53	13	3.012520E-06	29	0.69
240	4.089	3.078985E-05	2	0.53	13	7.530125E-06	5	0.69
241	6.520	1.998573E-05	36	0.69	12	3.065159E-06	5	1.60
242	6.581	2.144081E-05	3	1.60	6	3.259435E-06	4	1.23
243	8.542	2.812876E-05	6	0.53	10	3.292853E-06	9	0.69
244	6.481	1.564444E-05	2	0.53	10	5.499548E-06	5	1.23
245	10.346	2.094515E-05	24	0.90	15	2.022573E-06	24	1.23
246	6.649	1.727105E-05	3	0.69	12	2.597723E-06	4	1.23
247	4.192	1.461524E-05	16	1.60	13	3.486294E-06	18	1.60
248	3.630	1.510654E-05	20	1.60	14	4.161305E-06	22	1.23
249	3.964	1.583795E-05	19	1.60	3	3.995081E-06	23	1.60

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

			MAX HOURLY				MAX 24-HOUR	
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
250	4.353	1.469629E-05	21	1.60	20	3.376195E-06	21	1.60
251	7.228	2.323891E-05	24	0.90	17	3.215015E-06	22	1.60
252	5.374	2.361566E-05	23	0.90	17	4.580223E-06	23	0.90
253	7.234	2.718723E-05	23	0.69	11	3.758457E-06	23	0.69
254	10.305	2.789591E-05	34	0.53	11	2.707086E-06	1	0.69
255	12.573	3.024281E-05	5	0.53	11	2.405357E-06	5	0.69
256	8.147	2.522327E-05	1	0.69	15	3.095873E-06	2	1.23
257	4.389	1.624193E-05	6	1.60	7	3.700248E-06	18	1.60
258	9.540	2.483722E-05	23	0.90	16	2.597955E-06	23	0.90
259	6.499	2.532305E-05	18	0.53	10	3.896738E-06	21	0.90
260	23.998	1.953859E-05	31	1.60	13	8.141771E-07	31	1.60
261	10.409	2.453221E-05	24	0.53	15	2.741150E-06	20	0.69
262	7.274	2.371901E-05	24	0.90	9	3.259920E-06	23	0.90
263	12.531	2.525222E-05	21	0.90	10	2.015253E-06	33	1.60
264	9.142	1.483504E-05	3	1.60	18	1.622775E-06	4	1.60
265	4.551	1.496190E-05	23	1.60	20	3.287887E-06	22	1.60
266	4.675	1.295540E-05	18	1.60	18	2.771073E-06	18	1.23
267	4.710	2.017574E-05	23	0.90	14	4.283756E-06	21	1.60
268	9.269	2.464374E-05	8	0.69	14	2.658808E-06	8	0.69
269	10.181	3.290468E-05	23	0.69	11	3.232015E-06	23	0.69
270	14.658	2.753568E-05	36	0.69	10	1.878506E-06	34	0.69
271	5.594	1.513675E-05	36	1.60	17	2.705782E-06	32	1.60
272	6.259	1.578976E-05	1	1.60	4	2.522757E-06	1	1.60
273	11.440	2.515077E-05	12	0.90	16	2.198544E-06	15	1.23
274	11.541	2.535948E-05	21	0.53	13	2.197277E-06	21	0.69
275	5.280	1.354353E-05	21	1.60	8	2.565238E-06	17	1.23
276	3.644	1.268820E-05	15	1.60	21	3.482177E-06	15	1.60
277	18.077	2.528587E-05	23	0.69	14	1.398817E-06	19	0.90
278	7.659	2.632206E-05	23	0.53	14	3.436546E-06	21	0.69
279	7.214	2.539237E-05	22	0.53	12	3.519726E-06	23	0.69
280	8.533	2.515077E-05	23	0.90	9	2.947408E-06	22	0.90
281	4.059	1.260847E-05	18	1.23	14	3.105924E-06	20	1.23
282	12.713	2.326738E-05	17	0.90	12	1.830218E-06	17	0.90
283	7.474	2.749571E-05	12	0.69	14	3.678614E-06	9	0.90
284	7.788	2.763873E-05	18	0.69	13	3.549002E-06	18	0.69
285	7.590	2.271227E-05	5	0.90	16	2.992438E-06	5	1.23
286	10.557	2.323891E-05	20	0.90	13	2.201269E-06	20	1.23
287	10.891	2.528445E-05	34	0.69	10	2.321542E-06	1	1.60
288	11.631	3.787564E-05	36	0.90	16	3.256576E-06	3	1.60
289	10.353	1.461524E-05	5	1.60	17	1.411753E-06	6	1.23
290	11.083	2.617953E-05	20	0.69	13	2.362083E-06	18	1.23
291	5.303	1.376933E-05	23	1.60	24	2.596425E-06	20	1.23
292	6.293	1.306230E-05	22	1.60	1	2.075579E-06	18	1.23
293	9.298	2.014807E-05	14	0.90	13	2.168896E-06	14	1.23
294	4.221	1.247172E-05	17	1.60	8	2.954719E-06	19	1.60
295	17.600	2.435977E-05	17	0.69	11	1.384113E-06	11	0.90
296	9.039	2.468884E-05	17	0.90	14	2.731263E-06	17	0.90
297	6.830	2.348845E-05	22	1.23	14	3.439003E-06	22	1.23
298	5.367	1.487523E-05	2	1.60	18	2.771839E-06	4	1.60
299	7.292	2.145844E-05	18	0.90	15	2.942616E-06	19	0.90

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

			MAX HOURLY				MAX 24-HOUR	
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
300	15.762	2.491412E-05	19	0.69	12	1.707496E-06	27	0.69
301	7.895	1.459516E-05	33	1.60	23	1.448759E-06	29	1.60
302	10.384	2.222075E-05	35	0.90	15	2.139847E-06	35	1.23
303	12.031	2.634096E-05	25	0.53	13	2.189347E-06	24	0.69
304	15.608	2.942058E-05	16	0.90	12	1.885008E-06	5	0.69
305	8.602	2.587270E-05	7	0.90	12	3.007752E-06	7	0.90
306	7.422	2.692519E-05	22	0.53	12	3.627868E-06	22	0.69
307	10.748	2.957163E-05	18	0.69	11	2.741241E-06	23	0.69
308	4.133	1.415850E-05	3	1.60	8	2.304427E-06	4	1.23
309	5.327	2.043619E-05	5	1.60	7	3.873793E-06	5	1.60
310	3.857	1.526910E-05	5	1.60	2	3.959172E-06	20	1.60
311	3.241	1.404027E-05	7	1.60	1	4.332365E-06	16	1.60
312	5.539	1.325183E-05	16	1.60	13	2.392491E-06	17	1.60
313	8.191	2.117938E-05	19	0.90	15	2.585789E-06	18	1.23
314	9.774	1.845670E-05	20	0.90	15	1.888308E-06	22	1.23
315	14.414	2.429532E-05	31	0.90	12	1.685517E-06	28	0.90
316	7.994	1.499774E-05	36	1.60	15	1.876030E-06	36	1.60
317	5.920	1.263323E-05	8	1.60	4	2.133942E-06	9	1.23
318	4.596	1.239831E-05	4	1.60	22	2.697681E-06	3	1.23
319	9.627	2.018489E-05	13	0.90	21	2.094687E-06	12	1.23
320	8.569	1.841039E-05	29	0.90	15	2.148366E-06	23	1.23
321	11.832	1.370230E-05	11	1.60	16	1.158027E-06	11	1.60
322	14.022	1.145738E-05	13	1.60	14	8.170844E-07	13	1.60
323	5.034	1.303031E-05	10	1.60	8	2.588334E-06	5	1.60
324	7.253	1.476726E-05	4	1.60	9	2.036124E-06	2	1.60
325	2.910	1.235995E-05	8	1.60	8	4.246947E-06	8	1.60
326	4.204	1.367711E-05	18	1.60	16	3.253122E-06	12	1.60
327	5.568	2.162812E-05	22	0.90	9	3.884599E-06	23	1.23
328	3.756	1.383656E-05	5	1.60	9	3.683705E-06	5	1.60
329	7.124	1.382916E-05	5	1.60	8	1.941259E-06	4	1.60
330	3.910	1.167022E-05	17	1.60	21	2.985071E-06	15	1.60
331	21.484	2.171607E-05	28	0.90	13	1.010764E-06	22	0.90
332	11.938	2.164745E-05	9	0.90	12	1.813320E-06	18	1.60
333	13.881	1.881352E-05	20	0.90	14	1.355349E-06	21	1.23
334	11.868	2.525389E-05	23	0.90	9	2.127867E-06	23	1.23
335	9.339	1.324320E-05	32	1.23	16	1.418060E-06	28	1.23
336	4.242	1.311497E-05	8	1.60	21	3.091792E-06	5	1.23
337	4.767	1.319431E-05	13	1.60	15	2.767591E-06	13	1.23
338	4.016	1.230854E-05	14	1.60	1	3.064821E-06	15	1.60
339	8.708	2.118616E-05	21	1.23	14	2.432986E-06	22	0.90
340	7.112	1.315783E-05	25	1.60	13	1.850157E-06	21	1.60
341	9.354	2.133359E-05	23	0.90	13	2.280701E-06	22	0.90
342	8.844	1.441101E-05	36	1.60	3	1.629484E-06	12	1.60
343	11.914	2.179752E-05	10	0.90	11	1.829624E-06	9	1.23
344	10.625	2.084306E-05	9	0.90	14	1.962007E-06	11	1.60
345	7.018	2.207248E-05	3	0.90	12	3.136209E-06	2	0.90
346	11.073	1.275208E-05	4	1.60	11	1.151611E-06	5	1.60
347	5.844	1.229788E-05	19	1.60	13	2.104266E-06	21	1.60
348	6.953	1.311847E-05	10	1.60	1	1.886429E-06	20	1.60
349	8.983	1.855782E-05	21	0.90	10	2.066944E-06	30	1.60

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PLANT NAME: CRSTEN SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

			MAX HOURLY			MAX 24-HOUR		
DAY	RATIO	CONCENTRATION	DIRECTION	DISTANCE(KM)	HOUR	CONCENTRATION	DIRECTION	DISTANCE(KM)
350	4.633	1.360171E-05	32	1.60	3	2.936009E-06	32	1.60
351	14.915	2.486650E-05	8	1.60	10	1.667230E-06	30	1.23
352	5.195	1.292483E-05	12	1.60	1	2.488151E-06	13	1.23
353	3.069	1.356076E-05	5	1.60	24	4.418898E-06	5	1.60
354	5.394	1.341158E-05	23	1.60	16	2.486548E-06	23	1.60
355	11.005	1.359301E-05	7	1.60	20	1.235208E-06	18	1.60
356	14.572	1.708173E-05	11	0.90	10	1.172217E-06	13	1.60
357	4.816	1.335148E-05	5	1.60	20	2.772422E-06	5	1.60
358	4.297	1.476726E-05	7	1.60	21	3.436874E-06	7	1.23
359	5.575	1.448783E-05	6	1.60	3	2.598923E-06	6	1.23
360	6.070	1.824472E-05	22	0.90	15	3.005897E-06	17	1.60
361	3.471	1.309221E-05	5	1.60	24	3.382431E-06	5	1.60
362	8.152	1.200636E-05	21	1.60	13	1.472742E-06	21	1.60
363	4.847	1.345547E-05	5	1.60	18	2.776078E-06	5	1.60
364	7.599	1.394432E-05	5	1.60	2	1.835050E-06	7	1.23
365	11.637	1.377902E-05	32	1.60	12	1.184093E-06	5	1.60

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

MAXIMUM MEAN CONC= 6.7162E-07 DIRECTION= 5 DISTANCE= 1.2 KM

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6 KM
1	8.66469E-08	1.37284E-07	2.01037E-07	2.41644E-07	2.45550E-07
2	9.37104E-08	1.56499E-07	2.36415E-07	2.84506E-07	2.86773E-07
3	1.29294E-07	2.27688E-07	3.49623E-07	4.15823E-07	4.11651E-07
4	2.04298E-07	3.42665E-07	5.02405E-07	5.78741E-07	5.62897E-07
5	2.49871E-07	4.04781E-07	5.84513E-07	6.71624E-07	6.52227E-07
6	2.12692E-07	3.24396E-07	4.39212E-07	4.82588E-07	4.56218E-07
7	1.53041E-07	2.33570E-07	3.15733E-07	3.47554E-07	3.29094E-07
8	1.15005E-07	1.75045E-07	2.32755E-07	2.52871E-07	2.37599E-07
9	1.26761E-07	1.92204E-07	2.51832E-07	2.69910E-07	2.51025E-07
10	1.16948E-07	1.67635E-07	2.09611E-07	2.16453E-07	1.96025E-07
11	1.01577E-07	1.44764E-07	1.84631E-07	1.97273E-07	1.85020E-07
12	9.77579E-08	1.43595E-07	1.94641E-07	2.18933E-07	2.11637E-07
13	1.02277E-07	1.42503E-07	1.85161E-07	2.02764E-07	1.93830E-07
14	8.75342E-08	1.29568E-07	1.83431E-07	2.11847E-07	2.06740E-07
15	5.90737E-08	9.87182E-08	1.57862E-07	1.94927E-07	1.95853E-07
16	5.31826E-08	9.47320E-08	1.52384E-07	1.85484E-07	1.83533E-07
17	4.89622E-08	1.45552E-07	2.06320E-07	2.30709E-07	2.18016E-07
18	1.49217E-07	2.48304E-07	3.57211E-07	3.05707E-07	3.88655E-07
19	1.63286E-07	2.53196E-07	3.45277E-07	3.79741E-07	3.57841E-07
20	1.90937E-07	2.95921E-07	4.10763E-07	4.58124E-07	4.34129E-07
21	2.37466E-07	3.43864E-07	4.51514E-07	4.88743E-07	4.57173E-07
22	3.30540E-07	4.52423E-07	5.50039E-07	5.60994E-07	5.06115E-07
23	3.78150E-07	5.15543E-07	6.25063E-07	6.40176E-07	5.80493E-07
24	3.07180E-07	4.04291E-07	4.73297E-07	4.73184E-07	4.23689E-07
25	1.89737E-07	2.46501E-07	2.88402E-07	2.91642E-07	2.64635E-07
26	1.12764E-07	1.47661E-07	1.76985E-07	1.86296E-07	1.75891E-07
27	1.03094E-07	1.41543E-07	1.72179E-07	1.80850E-07	1.69792E-07
28	8.62511E-08	1.15918E-07	1.37689E-07	1.42670E-07	1.33597E-07
29	7.52597E-08	9.85274E-08	1.15478E-07	1.19044E-07	1.11123E-07
30	7.94383E-08	1.09152E-07	1.34236E-07	1.43257E-07	1.36400E-07
31	6.66032E-08	9.67861E-08	1.25877E-07	1.40009E-07	1.36753E-07
32	4.89550E-08	7.82148E-08	1.13760E-07	1.36834E-07	1.39075E-07
33	5.05374E-08	7.78461E-08	1.06266E-07	1.21884E-07	1.21242E-07
34	5.19304E-08	7.61708E-08	1.00704E-07	1.14664E-07	1.15748E-07
35	6.31475E-08	9.53054E-08	1.29799E-07	1.48677E-07	1.47790E-07
36	8.18103E-08	1.32212E-07	1.92854E-07	2.31354E-07	2.36364E-07

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY MAXIMUM 24-HOUR CONC= 7.5301E-06 DIRECTION= 5 DISTANCE= 0.7 KM DAY=240

HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR \ RANGE	0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6 KM
1	2.4457E-06 (170)	2.7071E-06 (254)	2.7720E-06 (93)	3.1826E-06 (93)	3.1592E-06 (215)
2	2.8931E-06 (244)	3.0726E-06 (244)	3.1362E-06 (345)	3.1249E-06 (214)	3.1098E-06 (214)
3	3.3242E-06 (244)	4.0905E-06 (244)	4.2960E-06 (244)	3.9512E-06 (244)	3.7188E-06 (28)
4	4.7208E-06 (226)	4.7475E-06 (226)	4.4568E-06 (97)	4.5897E-06 (59)	5.0420E-06 (187)
5	6.9609E-06 (240)	7.5301E-06 (240)	6.5393E-06 (240)	5.8828E-06 (172)	5.1138E-06 (172)
6	6.3499E-06 (240)	6.5953E-06 (240)	5.6158E-06 (240)	4.9540E-06 (15)	5.1633E-06 (15)
7	3.0821E-06 (111)	3.1563E-06 (184)	4.0870E-06 (16)	4.8071E-06 (16)	4.5544E-06 (16)
8	2.3332E-06 (268)	2.6588E-06 (268)	3.2116E-06 (325)	4.1919E-06 (325)	4.2469E-06 (325)
9	3.2638E-06 (195)	3.8589E-06 (195)	3.7246E-06 (195)	3.0016E-06 (195)	2.6098E-06 (54)
10	3.2096E-06 (195)	3.2872E-06 (195)	3.0541E-06 (169)	4.1621E-06 (96)	4.3807E-06 (96)
11	2.5534E-06 (119)	2.6500E-06 (169)	2.5463E-06 (169)	3.0337E-06 (90)	2.9792E-06 (90)
12	2.6610E-06 (191)	2.7096E-06 (191)	2.7259E-06 (169)	2.9437E-06 (326)	3.2531E-06 (326)
13	2.9311E-06 (152)	3.7437E-06 (152)	3.8222E-06 (152)	3.2902E-06 (152)	2.7200E-06 (337)
14	2.7024E-06 (195)	3.2739E-06 (116)	3.3933E-06 (116)	3.1058E-06 (48)	3.1020E-06 (48)
15	2.6286E-06 (173)	2.6617E-06 (163)	2.5492E-06 (276)	3.4318E-06 (276)	3.4822E-06 (276)
16	2.0461E-06 (173)	1.4529E-06 (57)	3.1902E-06 (311)	4.2721E-06 (311)	4.3324E-06 (311)
17	2.0895E-06 (227)	2.5239E-06 (57)	3.1649E-06 (57)	3.1565E-06 (35)	3.0865E-06 (35)
18	2.9957E-06 (284)	3.5490E-06 (284)	4.1029E-06 (159)	4.9838E-06 (159)	4.8544E-06 (159)
19	3.2612E-06 (230)	3.4729E-06 (230)	3.1110E-06 (230)	3.7637E-06 (310)	3.9529E-06 (310)
20	5.2051E-06 (230)	5.9729E-06 (230)	5.4308E-06 (230)	4.1761E-06 (24)	4.4817E-06 (24)
21	5.7012E-06 (198)	5.3691E-06 (198)	4.1608E-06 (198)	4.2267E-06 (267)	4.2838E-06 (267)
22	6.6308E-06 (198)	7.0066E-06 (198)	6.0594E-06 (198)	4.4978E-06 (71)	4.7951E-06 (71)
23	4.1270E-06 (224)	4.2582E-06 (224)	5.4031E-06 (232)	6.8201E-06 (233)	6.6378E-06 (233)
24	3.6794E-06 (224)	3.7762E-06 (139)	4.3165E-06 (139)	5.1065E-06 (232)	4.9899E-06 (232)
25	2.7677E-06 (203)	3.1511E-06 (203)	4.0189E-06 (139)	4.6845E-06 (139)	4.6095E-06 (139)
26	2.6569E-06 (117)	3.1719E-06 (117)	3.0499E-06 (117)	2.7180E-06 (155)	2.4491E-06 (155)
27	4.1646E-06 (117)	5.3534E-06 (117)	5.2437E-06 (117)	4.1303E-06 (117)	3.6682E-06 (125)
28	2.2267E-06 (202)	2.4972E-06 (202)	2.5865E-06 (32)	2.2457E-06 (32)	1.7636E-06 (166)
29	2.7390E-06 (166)	3.0125E-06 (239)	2.9237E-06 (239)	2.2747E-06 (239)	2.0386E-06 (349)
30	4.3150E-06 (166)	3.3419E-06 (166)	2.7255E-06 (128)	2.2133E-06 (128)	2.2250E-06 (65)
31	4.1339E-06 (166)	4.0365E-06 (166)	3.7246E-06 (166)	3.1746E-06 (166)	2.5351E-06 (166)
32	2.2327E-06 (220)	2.5199E-06 (220)	2.5288E-06 (220)	2.8949E-06 (350)	2.9360E-06 (350)
33	1.9222E-06 (239)	1.7711E-06 (270)	1.9044E-06 (128)	2.4963E-06 (50)	2.6473E-06 (50)
34	1.9675E-06 (189)	2.1947E-06 (189)	1.9305E-06 (189)	1.8772E-06 (50)	2.1494E-06 (207)
35	2.2509E-06 (170)	2.2133E-06 (170)	2.1005E-06 (302)	2.1394E-06 (302)	2.0347E-06 (302)
36	3.1494E-06 (170)	3.2091E-06 (170)	2.6869E-06 (170)	2.8712E-06 (288)	2.8728E-06 (288)

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PLANT NAME: CHSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 24-HOUR CONC= 5.9384E-06 DIRECTION= 5 DISTANCE= 0.9 KM DAY=172

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE DIR	0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6 KM
1	2.3442E-06 (254)	2.5538E-06 (170)	2.7416E-06 (256)	3.0528E-06 (215)	2.9714E-06 (93)
2	1.8908E-06 (144)	2.4277E-06 (345)	2.8572E-06 (256)	3.0959E-06 (256)	2.9127E-06 (256)
3	2.4867E-06 (226)	2.6292E-06 (226)	2.9935E-06 (63)	3.6427E-06 (63)	3.4938E-06 (63)
4	3.5476E-06 (244)	4.3379E-06 (244)	4.3793E-06 (244)	4.5681E-06 (187)	4.5345E-06 (59)
5	3.9497E-06 (111)	4.4187E-06 (172)	5.9384E-06 (172)	5.4995E-06 (244)	5.0901E-06 (244)
6	4.7025E-06 (111)	4.4516E-06 (111)	3.5977E-06 (111)	4.0624E-06 (240)	3.5413E-06 (104)
7	2.9231E-06 (240)	2.9505E-06 (305)	3.2279E-06 (137)	3.4369E-06 (358)	3.3717E-06 (358)
8	2.0717E-06 (191)	2.3945E-06 (184)	2.3800E-06 (283)	2.5584E-06 (336)	2.[illegible]36E-06 (336)
9	2.7466E-06 (243)	3.5035E-06 (283)	3.6786E-06 (283)	2.9951E-06 (283)	2.[illegible]3E-06 (200)
10	2.6371E-06 (191)	3.0917E-06 (169)	2.9457E-06 (96)	2.6171E-06 (169)	2.2491E-06 (54)
11	2.4318E-06 (195)	2.2996E-06 (119)	2.3708E-06 (90)	2.0132E-06 (89)	2.1935E-06 (89)
12	2.[illegible]42E-06 (195)	2.6266E-06 (152)	2.5040E-06 (152)	2.6165E-06 (337)	2.6323E-06 (337)
13	2.[illegible]238E-06 (191)	2.7333E-06 (191)	2.5944E-06 (194)	2.7676E-06 (337)	2.6345E-06 (152)
14	2.4841E-06 (116)	2.2284E-06 (163)	2.3789E-06 (48)	2.8803E-06 (56)	3.1020E-06 (56)
15	2.0590E-06 (163)	1.9361E-06 (173)	2.4969E-06 (163)	2.9846E-06 (330)	3.0648E-06 (338)
16	1.2419E-06 (212)	1.6392E-06 (173)	3.03[illegible]E-06 (57)	3.6432E-06 (57)	3.5404E-06 (57)
17	1.6299E-06 (296)	2.4703E-06 (296)	2.7[illegible]06 (296)	3.1245E-06 (57)	3.0059E-06 (360)
18	2.1888E-06 (227)	2.2907E-06 (160)	2.2343E-06 (284)	3.6902E-06 (257)	3.7003E-06 (257)
19	2.4970E-06 (284)	2.8764E-06 (284)	2.9426E-06 (299)	3.6959E-06 (34)	3.7724E-06 (34)
20	2.7612E-06 (198)	3.0011E-06 (193)	3.5697E-06 (201)	4.1650E-06 (230)	3.9592E-06 (310)
21	3.5940E-06 (230)	3.8546E-06 (230)	3.8967E-06 (259)	3.6444E-06 (46)	3.5747E-06 (46)
22	3.9018E-06 (189)	3.6357E-06 (253)	3.4698E-06 (306)	4.3933E-06 (198)	[illegible].0792E-06 (248)
23	3.8350E-06 (162)	3.9866E-06 (162)	4.6285E-06 (232)	5.0767E-06 (232)	4.7208E-06 (232)
24	3.2226E-06 (120)	3.7150E-06 (224)	4.2888E-06 (232)	4.1302E-06 (139)	3.8228E-06 (157)
25	2.2244E-06 (120)	2.9196E-06 (139)	3.2487E-06 (140)	3.2012E-06 (131)	3.3476E-06 (88)
26	2.2007E-06 (227)	2.1881E-06 (155)	2.6635E-06 (155)	2.4436E-06 (117)	2.3248E-06 (70)
27	2.3503E-06 (202)	2.6616E-06 (202)	2.5213E-06 (141)	3.4282E-06 (125)	2.9915E-06 (117)
28	2.0295E-06 (183)	2.3870E-06 (117)	2.2576E-06 (117)	1.9592E-06 (156)	1.6765E-06 (32)
29	2.3224E-06 (239)	1.9544E-06 (238)	1.9152E-06 (232)	1.9269E-06 (349)	1.8488E-06 (301)
30	2.5277E-06 (128)	2.9340E-06 (128)	2.3409E-06 (166)	2.1068E-06 (167)	2.0669E-06 (349)
31	2.7666E-06 (128)	3.2697E-06 (128)	3.1511E-06 (128)	2.5650E-06 (128)	2.0163E-06 (271)
32	1.8194E-06 (166)	1.9617E-06 (166)	2.1740E-06 (350)	2.4466E-06 (271)	2.7058E-06 (271)
33	1.4761E-06 (220)	1.6897E-06 (239)	1.7756E-06 (228)	1.9516E-06 (223)	2.0153E-06 (263)
34	1.8025E-06 (239)	1.8785E-06 (270)	1.8448E-06 (270)	1.7379E-06 (207)	2.0260E-06 (50)
35	1.7918E-06 (189)	2.1447E-06 (189)	2.0085E-06 (189)	1.7346E-06 (239)	1.7084E-06 (271)
36	1.5492E-06 (244)	1.8496E-06 (93)	2.4524E-06 (288)	2.4201E-06 (228)	2.7645E-06 (221)

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PLANT NAME: CASTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY MAXIMUM 3-HOUR CONC: 2.8474E-05 DIRECTION= 5 DISTANCE= 0.5 KM DAY=240 TIME PERIOD= 4

HIGHEST 3-HOUR CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6 *
1	1.3731E-05 (144, 4)	1.5019E-05 (144, 4)	1.2478E-05 (144, 4)	1.2643E-05 (93, 7)	1.2727E-05 (
2	1.3003E-05 (199, 5)	1.2816E-05 (199, 5)	1.4136E-05 (345, 5)	1.5085E-05 (303, 4)	1.3215E-05 (
3	1.3884E-05 (244, 4)	1.4653E-05 (244, 3)	1.5554E-05 (244, 3)	1.3442E-05 (244, 3)	1.2459E-05 (
4	1.9338E-05 (244, 4)	2.0018E-05 (244, 4)	1.6712E-05 (97, 4)	1.6212E-05 (183, 3)	1.4022E-05 (
5	2.8474E-05 (240, 4)	2.6984E-05 (240, 4)	2.0575E-05 (240, 4)	1.6500E-05 (244, 6)	1.5169E-05 (
6	2.3814E-05 (240, 4)	2.2308E-05 (240, 4)	1.9630E-05 (181, 3)	1.6199E-05 (181, 3)	1.2481E-05 (
7	1.9265E-05 (184, 4)	2.3029E-05 (184, 4)	2.1326E-05 (184, 4)	1.6166E-05 (184, 4)	1.1793E-05 (
8	1.4385E-05 (191, 4)	1.5822E-05 (191, 4)	1.3778E-05 (191, 4)	1.0802E-05 (92, 6)	1.0268E-05 (
9	1.5309E-05 (243, 5)	1.9957E-05 (190, 3)	2.2301E-05 (190, 3)	1.9652E-05 (190, 3)	1.5206E-05 (
10	1.7345E-05 (191, 6)	1.9986E-05 (191, 6)	1.7823E-05 (191, 6)	1.4245E-05 (237, 4)	1.0679E-05 (
11	2.0325E-05 (119, 4)	1.8282E-05 (119, 4)	1.3577E-05 (119, 4)	9.6328E-06 (169, 3)	8.7277E-06 (
12	1.3921E-05 (195, 4)	1.4090E-05 (109, 3)	1.1947E-05 (109, 3)	1.1227E-05 (326, 2)	1.2655E-05 (
13	2.1840E-05 (195, 4)	1.9276E-05 (152, 5)	1.8388E-05 (152, 5)	1.4155E-05 (152, 5)	1.0115E-05 (
14	2.1591E-05 (195, 4)	1.6045E-05 (195, 4)	1.1339E-05 (116, 4)	9.5056E-06 (116, 4)	8.9278E-06 (
15	2.0924E-05 (173, 4)	1.5081E-05 (173, 4)	1.1576E-05 (163, 4)	1.0757E-05 (338, 4)	1.1019E-05 (
16	1.6008E-05 (173, 4)	1.1451E-05 (173, 4)	9.8069E-06 (304, 4)	1.2402E-05 (311, 2)	1.2672E-05 (
17	1.6556E-05 (227, 4)	1.5704E-05 (227, 4)	1.5002E-05 (311, 4)	1.2263E-05 (73, 4)	1.1462E-05 (
18	1.7508E-05 (227, 4)	1.6693E-05 (227, 4)	1.5830E-05 (307, 4)	1.2105E-05 (307, 4)	1.1674E-05 (
19	1.4824E-05 (284, 4)	1.7692E-05 (284, 4)	1.6171E-05 (284, 4)	1.1999E-05 (284, 4)	1.0786E-05 (
20	1.9178E-05 (230, 4)	2.0810E-05 (230, 4)	1.7975E-05 (230, 4)	1.4805E-05 (286, 5)	1.3485E-05 (
21	1.9949E-05 (198, 5)	1.9513E-05 (198, 5)	1.5899E-05 (259, 4)	1.4131E-05 (168, 6)	1.2917E-05 (
22	2.4298E-05 (198, 4)	2.3554E-05 (198, 4)	1.8928E-05 (198, 4)	1.3404E-05 (306, 5)	1.2265E-05 (
23	2.2956E-05 (224, 5)	2.3890E-05 (224, 5)	2.1612E-05 (279, 5)	1.7387E-05 (279, 5)	1.4689E-05 (
24	1.9443E-05 (224, 5)	2.1132E-05 (139, 4)	1.9410E-05 (139, 4)	1.4588E-05 (139, 4)	1.3147E-05 (
25	1.5443E-05 (209, 6)	1.7203E-05 (209, 6)	1.5298E-05 (209, 6)	1.1753E-05 (110, 3)	1.1641E-05 (
26	1.7454E-05 (227, 5)	1.5859E-05 (227, 5)	1.1774E-05 (227, 5)	9.7498E-06 (178, 4)	9.5373E-06 (
27	1.8413E-05 (227, 5)	1.7347E-05 (227, 5)	1.4020E-05 (117, 5)	1.1675E-05 (125, 4)	1.2437E-05 (
28	1.1987E-05 (239, 5)	1.4086E-05 (239, 5)	1.3455E-05 (315, 5)	1.1563E-05 (315, 5)	1.3062E-05 (
29	1.5153E-05 (238, 5)	1.5480E-05 (239, 5)	1.4345E-05 (32, 5)	1.3100E-05 (32, 5)	1.0500E-05 (
30	1.9639E-05 (166, 4)	1.5551E-05 (166, 4)	1.5442E-05 (227, 6)	1.3338E-05 (351, 4)	1.1582E-05 (
31	1.6980E-05 (166, 4)	1.5331E-05 (166, 4)	1.3732E-05 (190, 6)	1.1793E-05 (190, 6)	1.0324E-05 (
32	9.3824E-06 (220, 5)	1.0291E-05 (220, 5)	1.0422E-05 (225, 6)	1.2863E-05 (254, 6)	1.3836E-05 (
33	8.3410E-06 (270, 5)	1.0050E-05 (202, 5)	9.6856E-06 (202, 5)	9.9116E-06 (228, 6)	1.0756E-05 (
34	1.5740E-05 (189, 6)	1.7558E-05 (189, 6)	1.5438E-05 (189, 6)	1.1209E-05 (189, 6)	1.2548E-05 (
35	.6824E-05 (170, 4)	1.7134E-05 (189, 6)	1.5951E-05 (189, 6)	1.2422E-05 (202, 5)	1.0874E-05 (
36	1.6794E-05 (170, 4)	1.5570E-05 (170, 4)	1.6069E-05 (288, 6)	1.7080E-05 (288, 6)	1.5980E-05 (

Best Available Document

PLANT NAME: CRSTEM SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 3-HOUR CONC= 2.1721E-05 DIRECTION= 23 DISTANCE= 0.7 KM DAY=279 TIME PERIOD= 5

SECOND HIGHEST 3-HOUR CONCENTRATION AT EACH RECEPTOR

DIR \ RANGE	0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6
1	1.3495E-05 (254, 4)	1.4215E-05 (254, 4)	1.1999E-05 (254, 4)	1.0760E-05 (272, 2)	1.2505E-05
2	1.2816E-05 (244, 4)	1.2291E-05 (345, 5)	1.2934E-05 (303, 4)	1.2380E-05 (345, 5)	1.3001E-05
3	1.3224E-05 (226, 4)	1.3403E-05 (244, 4)	1.3132E-05 (97, 5)	1.3295E-05 (221, 3)	1.1851E-05
4	1.7656E-05 (226, 4)	1.7410E-05 (226, 5)	1.5950E-05 (244, 4)	1.4869E-05 (269, 3)	1.3785E-05
5	1.8940E-05 (111, 5)	1.6657E-05 (134, 4)	1.6912E-05 (212, 3)	1.5503E-05 (212, 3)	1.4560E-05
6	1.9958E-05 (111, 4)	2.1482E-05 (111, 4)	1.8142E-05 (111, 4)	1.2765E-05 (135, 6)	1.2009E-05
7	1.4862E-05 (74, 4)	1.7639E-05 (74, 4)	1.6557E-05 (137, 4)	1.3431E-05 (236, 4)	1.1653E-05
8	1.1520E-05 (268, 4)	1.3056E-05 (268, 4)	1.1488E-05 (137, 4)	9.9302E-06 (191, 4)	9.6786E-06
9	1.3828E-05 (190, 3)	1.8314E-05 (243, 5)	1.6906E-05 (243, 5)	1.3453E-05 (283, 4)	1.1765E-05
10	1.5799E-05 (195, 5)	1.5454E-05 (190, 3)	1.6243E-05 (237, 4)	1.3043E-05 (191, 6)	1.0675E-05
11	1.3830E-05 (195, 5)	1.3609E-05 (169, 3)	1.2885E-05 (169, 3)	9.2559E-06 (319, 5)	8.3565E-06
12	1.3852E-05 (119, 4)	1.1626E-05 (195, 4)	1.1238E-05 (169, 3)	1.1019E-05 (273, 6)	1.0505E-05
13	1.5320E-05 (152, 5)	1.7386E-05 (195, 4)	1.5036E-05 (268, 5)	1.2270E-05 (268, 5)	9.7874E-06
14	1.2424E-05 (173, 4)	1.2307E-05 (163, 4)	1.0792E-05 (163, 4)	8.8890E-06 (247, 3)	8.9133E-06
15	1.2512E-05 (195, 4)	1.1301E-05 (163, 4)	9.2884E-06 (173, 4)	1.0353E-05 (311, 8)	1.0571E-05
16	9.7124E-06 (212, 5)	8.7828E-06 (304, 4)	9.1786E-06 (311, 2)	8.3352E-06 (57, 2)	8.5102E-06
17	1.0284E-05 (313, 4)	1.4557E-05 (313, 4)	1.3220E-05 (160, 3)	1.2184E-05 (313, 4)	8.9719E-06
18	1.3576E-05 (284, 5)	1.6187E-05 (307, 4)	1.4635E-05 (284, 5)	1.1660E-05 (257, 5)	1.1228E-05
19	1.3711E-05 (230, 4)	1.4462E-05 (201, 4)	1.3407E-05 (201, 4)	1.1133E-05 (299, 5)	9.3384E-06
20	1.2918E-05 (230, 5)	1.4515E-05 (230, 6)	1.5916E-05 (230, 6)	1.3509E-05 (230, 6)	1.1366E-05
21	1.7158E-05 (230, 5)	1.6537E-05 (274, 5)	1.5671E-05 (198, 5)	1.2835E-05 (259, 4)	1.1689E-05
22	1.9622E-05 (210, 5)	1.8970E-05 (253, 5)	1.7328E-05 (127, 5)	1.3402E-05 (180, 5)	1.2081E-05
23	1.9816E-05 (173, 5)	2.1721E-05 (279, 5)	1.9571E-05 (224, 5)	1.7272E-05 (327, 5)	1.4251E-05
24	1.8925E-05 (120, 4)	1.9038E-05 (224, 5)	1.6481E-05 (303, 5)	1.2608E-05 (303, 5)	1.1656E-05
25	1.2766E-05 (303, 5)	1.4389E-05 (140, 4)	1.4008E-05 (140, 4)	1.1295E-05 (209, 6)	1.0855E-05
26	1.1098E-05 (108, 5)	1.2235E-05 (108, 5)	1.1232E-05 (165, 6)	9.4560E-06 (155, 6)	8.2155E-06
27	1.2713E-05 (117, 4)	1.4065E-05 (117, 5)	1.3183E-05 (227, 5)	1.1166E-05 (117, 5)	1.1119E-05
28	1.0651E-05 (202, 4)	1.1982E-05 (315, 5)	1.2674E-05 (32, 5)	1.1216E-05 (166, 3)	8.7607E-06
29	1.3033E-05 (239, 5)	1.5635E-05 (238, 5)	1.4235E-05 (239, 5)	1.0466E-05 (239, 5)	1.0214E-05
30	1.4341E-05 (166, 5)	1.4657E-05 (227, 6)	1.3924E-05 (196, 6)	1.2776E-05 (55, 5)	1.0994E-05
31	1.2663E-05 (128, 4)	1.3097E-05 (128, 4)	1.2666E-05 (156, 4)	1.1633E-05 (166, 6)	9.1879E-06
32	8.4288E-06 (220, 4)	9.3536E-06 (220, 4)	1.0315E-05 (220, 5)	1.1959E-05 (350, 1)	1.2855E-05
33	8.2513E-06 (239, 4)	9.7280E-06 (269, 4)	9.1940E-06 (126, 5)	8.9042E-06 (128, 5)	1.0367E-05
34	1.1422E-05 (239, 5)	9.3949E-06 (191, 5)	8.4377E-06 (290, 6)	1.0193E-05 (239, 3)	1.0491E-05
35	1.4333E-05 (189, 6)	1.5702E-05 (170, 4)	1.4391E-05 (302, 5)	1.2055E-05 (189, 6)	9.4398E-06
36	1.0763E-05 (144, 4)	1.2985E-05 (144, 4)	1.1910E-05 (93, 3)	1.0998E-05 (221, 6)	1.2211E-05

PLANT NAME: CRSTEN SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY MAXIMUM 1-HOUR CONC= 3.9210E-05 DIRECTION= 24 DISTANCE= 0.5 KM DAY=194 HOUR=14

HIGHEST 1-HOUR CONCENTRATION AT EACH RECEPTOR

DIR \ RANGE	0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.6
1	3.3554E-05 (244,10)	3.1033E-05 (244,10)	2.7691E-05 (261,11)	2.2774E-05 (261,11)	1.9831E-05
2	3.5644E-05 (244,10)	3.3089E-05 (244,10)	2.4208E-05 (93,13)	2.5105E-05 (303,11)	2.1087E-05
3	2.3876E-05 (226,11)	2.8773E-05 (144, 9)	2.6952E-05 (144, 9)	2.8190E-05 (211,11)	2.4272E-05
4	3.0220E-05 (196,11)	3.1337E-03 (244,11)	2.8199E-05 (244,11)	2.6524E-05 (269, 9)	2.6895E-05
5	3.1345E-05 (190,15)	3.2366E-05 (190,15)	2.7330E-05 (212, 9)	2.6834E-05 (212, 8)	2.3698E-05
6	3.2488E-05 (111,13)	2.8182E-05 (194,16)	2.6052E-05 (255, 8)	2.2343E-05 (255, 8)	1.7893E-05
7	2.9181E-05 (236,12)	2.8953E-05 (236,12)	2.5873E-05 (305,12)	2.2029E-05 (150,11)	2.3251E-05
8	2.7655E-05 (191,11)	2.6912E-05 (119,15)	2.7087E-05 (119,15)	2.5564E-05 (261,10)	2.4866E-05
9	2.9210E-05 (170,11)	2.9328E-05 (130,14)	2.7187E-05 (130,14)	2.5923E-05 (190, 7)	2.1579E-05
10	3.2436E-05 (191,16)	3.3364E-05 (191,16)	3.1086E-05 (174,11)	2.6479E-05 (237,11)	2.1436E-05
11	2.9181E-05 (119,10)	2.9017E-05 (225,13)	2.6624E-05 (225,13)	2.3351E-05 (87, 9)	2.3813E-05
12	2.9738E-05 (174,12)	2.7702E-05 (189, 9)	2.7376E-05 (191,17)	2.3592E-05 (307, 9)	2.0388E-05
13	3.0439E-05 (191,12)	3.0616E-05 (183, 9)	2.7092E-05 (194,10)	2.4399E-05 (194,10)	1.9010E-05
14	3.0702E-05 (195,12)	2.6695E-05 (191,14)	2.5216E-05 (190,10)	2.0436E-05 (259, 8)	1.6858E-05
15	3.5354E-05 (173,12)	2.9978E-05 (163, 9)	3.0160E-05 (163,11)	2.4047E-05 (163,11)	1.6952E-05
16	2.9137E-05 (212,13)	2.6348E-05 (304,12)	2.9421E-05 (304,12)	2.3741E-05 (304,12)	1.6831E-05
17	2.5706E-05 (227,11)	2.4360E-05 (295,11)	2.4689E-05 (296,14)	2.6868E-05 (188,10)	2.3563E-05
18	3.0883E-05 (190,14)	2.9673E-05 (120, 9)	2.7558E-05 (307,11)	1.9964E-05 (307,11)	1.8240E-05
19	2.8722E-05 (230,13)	2.7353E-05 (284,12)	2.7267E-05 (163,12)	2.4656E-05 (163,12)	1.9256E-05
20	2.8514E-05 (230,11)	2.6504E-05 (230,11)	2.5642E-05 (160,16)	2.1261E-05 (124,17)	1.8803E-05
21	3.0442E-05 (189,11)	2.9251E-05 (230,15)	2.5733E-05 (307,15)	2.2329E-05 (133,16)	2.0853E-05
22	3.4823E-05 (173,13)	2.9425E-05 (230,14)	2.5511E-05 (188,13)	2.4754E-05 (108,17)	2.0566E-05
23	3.5354E-05 (183,14)	3.2905E-05 (269,11)	2.7414E-05 (224,14)	2.6372E-05 (234,11)	2.3251E-05
24	3.9210E-05 (194,14)	3.1871E-05 (173,14)	2.5985E-05 (173,14)	2.3475E-05 (253, 9)	2.0593E-05
25	3.2708E-05 (194,14)	2.6980E-05 (209,16)	2.6005E-05 (188,15)	2.5979E-05 (224, 9)	2.3228E-05
26	2.7013E-05 (202,11)	3.1044E-05 (239,12)	2.8053E-05 (239,12)	2.6037E-05 (220, 9)	2.2920E-05
27	2.8666E-05 (227,14)	2.8038E-05 (227,14)	2.5982E-05 (162,17)	2.5222E-05 (162,17)	2.0408E-05
28	3.0354E-05 (228,11)	3.0141E-05 (190,16)	2.7646E-05 (160,17)	2.6675E-05 (160,17)	2.1537E-05
29	2.6735E-05 (238,13)	2.6730E-05 (239,14)	2.7244E-05 (239,16)	2.3081E-05 (239,16)	1.7507E-05
30	2.9642E-05 (166,13)	2.8151E-05 (166,11)	2.7476E-05 (304,15)	2.4765E-05 (304,15)	1.9309E-05
31	2.6191E-05 (166,12)	2.3918E-05 (120,16)	2.4837E-05 (270,14)	2.3074E-05 (315,12)	1.9539E-05
32	2.7666E-05 (220,13)	2.7862E-05 (220,13)	2.5775E-05 (225,17)	2.3233E-05 (225,17)	1.8941E-05
33	2.4930E-05 (270,13)	2.9184E-05 (269,12)	2.7441E-05 (269,12)	1.9989E-05 (269,12)	2.0152E-05
34	3.4267E-05 (239,13)	2.8617E-05 (189,16)	2.5289E-05 (270, 9)	2.1367E-05 (270, 9)	1.6847E-05
35	3.0365E-05 (239,13)	3.1737E-05 (191,15)	2.7390E-05 (191,15)	2.2200E-05 (239,10)	1.9019E-05
36	2.6201E-05 (170,12)	3.2412E-05 (288,16)	3.7876E-05 (288,16)	3.4322E-05 (288,16)	2.7890E-05

PLANT NAME: CNSTEN SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 1-HOUR CONC= 3.4929E-05 DIRECTION= 15 DISTANCE= 0.5 KM DAY=212 HOUR=13

SECOND HIGHEST 1-HOUR CONCENTRATION AT EACH RECEPTOR

DIR \ RANGE	0.5 KM	0.7 KM	0.9 KM	1.2 KM	1.4
1	3.1656E-05 (119,14)	3.0316E-05 (119,14)	2.4598E-05 (211,13)	2.0477E-05 (211,13)	1.6921E-05
2	3.0790E-05 (240,13)	2.4581E-05 (244, 9)	2.3178E-05 (153,14)	2.0986E-05 (244, 7)	1.8404E-05
3	2.3640E-05 (244, 9)	2.3767E-05 (236,14)	2.5803E-05 (211,11)	2.3030E-05 (174, 7)	2.2210E-05
4	2.8372E-05 (226,13)	3.0136E-05 (236,14)	2.7186E-05 (236,14)	2.5635E-05 (183, 7)	2.1159E-05
5	3.0259E-05 (240,10)	2.9609E-05 (212, 9)	2.6912E-05 (191, 8)	2.3002E-05 (183, 8)	2.0636E-05
6	3.0542E-05 (236,13)	2.7433E-05 (126,14)	2.5381E-05 (205,13)	2.1034E-05 (1,10)	1.7204E-05
7	2.8954E-05 (240, 9)	2.8508E-05 (240, 9)	2.5419E-05 (150,11)	2.1994E-05 (160, 5)	1.7224E-05
8	2.1436E-05 (268,14)	2.6291E-05 (191,11)	2.5373E-05 (261,10)	2.2834E-05 (351,10)	2.1115E-05
9	2.7655E-05 (191,11)	2.8735E-05 (170,11)	2.5304E-05 (190, 7)	2.3956E-05 (305,14)	2.1169E-05
10	2.8770E-05 (196,13)	2.9595E-05 (174,11)	2.7376E-05 (195,17)	2.4171E-05 (174,11)	1.6832E-05
11	2.8061E-05 (183,11)	2.8953E-05 (119,10)	2.4390E-05 (150, 8)	2.2862E-05 (144, 8)	1.9839E-05
12	2.8749E-05 (195,11)	2.7496E-05 (203,14)	2.5252E-05 (307, 9)	2.3098E-05 (227, 7)	1.8739E-05
13	2.9525E-05 (119,12)	2.7753E-05 (189,10)	2.5415E-05 (183, 9)	2.2835E-05 (284, 9)	1.8248E-05
14	2.8412E-05 (191,14)	2.5942E-05 (195,10)	2.4334E-05 (259, 8)	2.0301E-05 (190,10)	1.5543E-05
15	3.4929E-05 (212,13)	2.7561E-05 (163,11)	2.5198E-05 (163, 9)	2.0959E-05 (126,12)	1.6943E-05
16	2.6134E-05 (173,12)	2.2137E-05 (160, 8)	2.1108E-05 (160, 8)	1.8042E-05 (150,14)	1.4850E-05
17	2.4986E-05 (295,11)	2.3592E-05 (227,11)	2.3734E-05 (188,10)	2.1810E-05 (296,14)	1.6829E-05
18	2.8032E-05 (194,13)	2.9572E-05 (307,11)	2.5120E-05 (141, 9)	1.9411E-05 (29,10)	1.6592E-05
19	2.8716E-05 (189,13)	2.6914E-05 (300,12)	2.3921E-05 (146,14)	2.1345E-05 (237,12)	1.7043E-05
20	2.5893E-05 (198,14)	2.6180E-05 (290,13)	2.5642E-05 (210,16)	2.0918E-05 (160,16)	1.6460E-05
21	2.9716E-05 (230,15)	2.6613E-05 (237,13)	2.5653E-05 (278,11)	2.2185E-05 (307,15)	1.7654E-05
22	2.9883E-05 (230,14)	2.9102E-05 (210,13)	2.5252E-05 (193,17)	2.3488E-05 (297,14)	1.9911E-05
23	3.4258E-05 (160,12)	2.9290E-05 (224,14)	2.7102E-05 (234,11)	2.3695E-05 (334, 9)	2.1386E-05
24	3.0059E-05 (173,14)	2.8944E-05 (269,11)	2.4365E-05 (177,11)	2.2428E-05 (139, 8)	1.7702E-05
25	3.0267E-05 (210,14)	2.6043E-05 (290,14)	2.6005E-05 (236,15)	2.3700E-05 (110, 7)	2.0360E-05
26	2.6296E-05 (67,12)	3.0003E-05 (202,11)	2.5559E-05 (220, 9)	2.3475E-05 (234, 7)	2.0593E-05
27	2.7239E-05 (212,16)	2.6767E-05 (190,16)	2.2800E-05 (117,15)	2.0335E-05 (41,10)	1.8471E-05
28	2.9785E-05 (183,15)	2.8509E-05 (202,12)	2.6553E-05 (183,17)	2.2134E-05 (183,17)	1.7459E-05
29	2.6267E-05 (166,13)	2.6139E-05 (202,14)	2.6584E-05 (253,17)	2.2757E-05 (253,17)	1.7428E-05
30	2.9557E-05 (166,12)	2.7263E-05 (220,12)	2.4707E-05 (227,16)	2.1946E-05 (351,11)	1.9227E-05
31	2.3067E-05 (120,11)	2.3340E-05 (270,14)	2.4295E-05 (315,12)	2.0678E-05 (270,14)	1.8484E-05
32	2.4751E-05 (239,11)	2.7079E-05 (220,11)	2.2718E-05 (220,11)	2.0046E-05 (315,10)	1.8091E-05
33	2.4751E-05 (239,11)	2.6730E-05 (239,11)	2.4085E-05 (202,13)	1.9772E-05 (202,13)	1.6559E-05
34	2.9721E-05 (189,16)	2.8185E-05 (191,15)	2.5289E-05 (290,16)	2.1366E-05 (290,16)	1.6255E-05
35	2.7063E-05 (170,10)	2.8387E-05 (183,10)	2.4333E-05 (228,10)	2.1673E-05 (304,14)	1.8739E-05
36	2.4702E-05 (287,10)	2.9855E-05 (144,10)	2.7704E-05 (144,10)	2.7712E-05 (228, 9)	2.4172E-05

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

MAXIMUM DAILY CONCENTRATIONS

DAY	24-HOUR CONCENTRATION	DIRECTION	DISTANCE
240	7.5301E-06	5	0.69
198	7.0046E-06	22	0.69
233	6.8201E-06	23	1.23
230	5.9729E-06	20	0.69
172	5.9384E-06	5	0.90
244	5.4995E-06	5	1.23
117	5.3534E-06	27	0.69
15	5.1633E-06	6	1.60
232	5.1065E-06	24	1.23
187	5.0420E-06	4	1.60
159	4.9838E-06	18	1.23
16	4.8071E-06	7	1.23
71	4.7951E-06	22	1.60
226	4.7475E-06	4	0.69
111	4.7025E-06	6	0.53
139	4.6845E-06	25	1.23
142	4.6609E-06	5	1.23
59	4.5897E-06	4	1.23
252	4.5802E-06	23	0.90
24	4.4817E-06	20	1.60
97	4.4568E-06	4	0.90
353	4.4189E-06	5	1.60
96	4.3807E-06	10	1.60
311	4.3324E-06	16	1.60
166	4.3150E-06	30	0.53
267	4.2838E-06	21	1.60
224	4.2582E-06	23	0.69
325	4.2469E-06	8	1.60
63	4.1943E-06	4	1.23
248	4.1613E-06	22	1.23
157	4.1128E-06	24	1.23
33	4.0937E-06	5	1.60
249	3.9951E-06	23	1.60
162	3.9866E-06	23	0.69
310	3.9592E-06	20	1.60
103	3.9393E-06	5	1.60
25	3.9152E-06	20	1.60
144	3.9037E-06	4	0.90
189	3.9018E-06	22	0.53
181	3.8980E-06	4	1.23
259	3.8967E-06	21	0.90
149	3.8898E-06	5	1.23
327	3.8846E-06	23	1.23
309	3.8738E-06	5	1.60
182	3.8646E-06	5	1.23
195	3.8589E-06	9	0.69
152	3.8222E-06	13	0.90
136	3.8095E-06	6	1.23
34	3.7724E-06	19	1.60
17	3.7605E-06	24	1.60

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PLANT NAME: CRSTER SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

MAXIMUM 3-HOURLY CONCENTRATIONS

DAY	3-HOUR CONCENTRATION	DIRECTION	DISTANCE	TIME PERIOD
240	2.8474E-05	5	0.53	4
240	2.6984E-05	5	0.69	4
198	2.4298E-05	22	0.53	4
224	2.3890E-05	23	0.69	5
240	2.3814E-05	6	0.53	4
198	2.3554E-05	22	0.69	4
184	2.3029E-05	7	0.69	4
224	2.2956E-05	23	0.53	5
240	2.2308E-05	6	0.69	4
190	2.2391E-05	9	0.90	3
195	2.1840E-05	13	0.53	4
279	2.1721E-05	23	0.69	5
279	2.1612E-05	23	0.90	5
195	2.1591E-05	14	0.53	4
111	2.1482E-05	6	0.69	4
184	2.1326E-05	7	0.90	4
306	2.1175E-05	23	0.69	4
139	2.1132E-05	24	0.69	4
173	2.0924E-05	15	0.53	4
230	2.0810E-05	20	0.69	4
240	2.0575E-05	5	0.90	4
162	2.0340E-05	23	0.69	5
119	2.0325E-05	11	0.53	4
269	2.0184E-05	23	0.69	4
244	2.0018E-05	4	0.69	4
198	1.9989E-05	21	0.53	5
191	1.9986E-05	10	0.69	6
111	1.9958E-05	6	0.53	4
190	1.9957E-05	[illegible]	0.69	3
173	1.9816E-05	23	0.53	5
190	1.9652E-05	9	1.23	3
162	1.9645E-05	23	0.53	5
166	1.9639E-05	30	0.53	4
181	1.9630E-05	6	0.90	3
210	1.9622E-05	22	0.53	5
224	1.9571E-05	23	0.90	5
198	1.9513E-05	21	0.69	5
224	1.9443E-05	24	0.53	5
139	1.9410E-05	24	0.90	4
306	1.9368E-05	23	0.90	4
244	1.9338E-05	4	0.53	4
152	1.9276E-05	13	0.69	5
184	1.9265E-05	7	0.53	4
230	1.9178E-05	20	0.53	4
224	1.9038E-05	24	0.69	5
253	1.8970E-05	22	0.69	5
111	1.8940E-05	5	0.53	5
198	1.8928E-05	22	0.90	4
120	1.8925E-05	24	0.53	4
181	1.8550E-05	6	0.69	3

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PLANT NAME: CNSTEK SIMULATION RUN POLLUTANT: TSP EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

MAXIMUM HOURLY CONCENTRATIONS

DAY	1-HOUR CONCENTRATION	DIRECTION	DISTANCE	HOUR
194	3.9210E-05	24	0.53	14
288	3.7876E-05	36	0.90	16
264	3.5644E-05	2	0.53	10
173	3.5354E-05	15	0.53	12
183	3.5354E-05	23	0.53	14
212	3.4929E-05	15	0.53	13
173	3.4823E-05	22	0.53	13
288	3.4322E-05	36	1.23	16
239	3.4267E-05	34	0.53	13
150	3.4258E-05	23	0.53	12
244	3.3554E-05	1	0.53	10
191	3.3364E-05	10	0.69	16
244	3.3089E-05	2	0.69	10
269	3.2905E-05	23	0.69	11
194	3.2708E-05	25	0.53	14
111	3.2488E-05	6	0.53	13
191	3.2436E-05	10	0.53	16
288	3.2412E-05	36	0.69	16
190	3.2366E-05	5	0.69	15
173	3.1871E-05	24	0.69	14
269	3.1748E-05	23	0.53	11
191	3.1737E-05	35	0.69	15
119	3.1656E-05	1	0.53	14
190	3.1345E-05	5	0.53	15
244	3.1337E-05	4	0.69	11
119	3.1164E-05	23	0.53	13
174	3.1086E-05	10	0.90	11
239	3.1044E-05	26	0.69	12
244	3.1033E-05	1	0.69	10
190	3.0883E-05	18	0.53	14
173	3.0859E-05	23	0.53	13
240	3.0799E-05	2	0.53	13
195	3.0702E-05	14	0.53	12
183	3.0616E-05	13	0.69	9
236	3.0542E-05	6	0.53	13
189	3.0442E-05	21	0.53	11
191	3.0439E-05	13	0.53	12
239	3.0365E-05	35	0.53	13
228	3.0354E-05	28	0.53	11
119	3.0316E-05	1	0.69	14
210	3.0267E-05	25	0.53	14
240	3.0259E-05	5	0.53	10
255	3.0213E-05	5	0.53	11
196	3.0220E-05	4	0.53	11
163	3.0160E-05	15	0.90	11
190	3.0141E-05	28	0.69	16
236	3.0136E-05	4	0.69	14
173	3.0059E-05	24	0.53	14
202	3.0003E-05	26	0.69	11
163	2.9978E-05	15	0.69	9

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APPENDIX 2

REFERENCE METHOD FOR DETERMINATION OF SUSPENDED PARTICULATES IN THE ATMOSPHERE (HIGH VOLUME METHOD)

REFERENCE METHOD*

APPENDIX B—REFERENCE METHOD FOR THE DETERMINATION OF SUSPENDED PARTICULATES IN THE ATMOSPHERE (HIGH VOLUME METHOD)

1. *Principle and Applicability.*

1.1 Air is drawn into a covered housing and through a filter by means of a high-flow-rate blower at a flow rate (1.13 to 1.70 m.³/min.; 40 to 60 ft.³/min.) that allows suspended particles having diameters of less than 100 μm. (Stokes equivalent diameter) to pass to the filter surface. (1) Particles within the size range of 100 to 0.1μm. diameter are ordinarily collected on glass fiber filters. The mass concentration of suspended particulates in the ambient air (μg./m.³) is computed by measuring the mass of collected particulates and the volume of air sampled.

1.2 This method is applicable to measurement of the mass concentration of suspended particulates in ambient air. The size of the sample collected is usually adequate for other analyses.

2. *Range and Sensitivity.*

2.1 When the sampler is operated at an average flow rate of 1.70 m.³/min. (60 ft.³/min.) for 24 hours, an adequate sample will be obtained even in an atmosphere having concentrations of suspended particulates as low as 1 μg./m.³. If particulate levels are unusually high, a satisfactory sample may be obtained in 6 to 8 hours or less. For determination of average concentrations of suspended particulates in ambient air, a standard sampling period of 24 hours is recommended.

2.2 Weights are determined to the nearest milligram, airflow rates are determined to the nearest 0.03 m.³/min. (1.0 ft.³/min.), times are determined to the nearest 2 minutes, and mass concentrations are reported to the nearest microgram per cubic meter.

3. *Interferences.*

3.1 Particulate matter that is oily, such as photochemical smog or wood smoke, may block the filter and cause a rapid drop in airflow at a nonuniform rate. Dense fog or high humidity can cause the filter to become too wet and severely reduce the airflow through the filter.

3.2 Glass-fiber filters are comparatively insensitive to changes in relative humidity, but collected particulates can be hygroscopic. (2)

4. *Precision, Accuracy, and Stability.*

4.1 Based upon collaborative testing, the relative standard deviation (coefficient of variation) for single analyst variation (repeatability of the method) is 3.0 percent. The corresponding value for multilaboratory variation (reproducibility of the method) is 3.7 percent. (3)

4.2 The accuracy with which the sampler measures the true average concentration depends upon the constancy of the airflow rate through the sampler. The airflow rate is affected by the concentration and the nature of the dust in the atmosphere. Under these conditions the error in the measured average concentration may be in excess of ±50 percent of the true average concentration, depending on the amount of reduction of airflow rate and on the variation of the mass concentration of dust with time during the 24-hour sampling period. (4)

5. *Apparatus.*

5.1 *Sampling.*

5.1.1 *Sampler.* The sampler consists of three units: (1) the faceplate and gasket, (2) the filter adapter assembly, and (3) the motor unit. Figure B1 shows an exploded view of these parts, their relationship to each other, and how they are assembled. The sampler must be capable of passing environmental air through a 406.5 cm.² (63 in.²) portion of a clean 20.3 by 25.4 cm. (8- by 10-in.) glass-fiber filter at a rate of at least 1.70 m.³/min. (60 ft.³/min.). The motor must be capable of continuous operation for 24-hour periods with input voltages ranging from 110 to 120 volts, 50–60 cycles alternating current and must have third-wire safety ground. The housing for the motor unit may be of any convenient construction so long as the unit remains airtight and leak-free. The life of the sampler motor can be extended by lowering the voltage by about 10 percent with a small "buck or boost" transformer between the sampler and power outlet.

5.1.2 *Sampler Shelter.* It is important that the sampler be properly installed in a suitable shelter. The shelter is subjected to extremes of temperature, humidity, and all types of air pollutants. For these reasons the materials of the shelter must be chosen carefully. Properly painted exterior plywood or heavy gauge aluminum serve well. The sampler must be mounted vertically in the shelter so that the glass-fiber filter is parallel with the ground. The shelter must be provided with a roof so that the filter is protected from precipitation and debris. The internal arrangement and configuration of a suitable shelter with a gable roof are shown in Figure B2. The clearance area between the main housing and the roof at its closest point should be 580.5±193.5 cm.² (90±30 in.²). The main housing should be rectangular, with dimensions of about 29 by 36 cm. (11½ by 14 in.).

5.1.3 *Rotameter.* Marked in arbitrary units, frequently 0 to 70, and capable of being calibrated. Other devices of at least comparable accuracy may be used.

5.1.4 *Orifice Calibration Unit.* Consisting of a metal tube 7.6 cm. (3 in.) ID and 15.9 cm. (6¼ in.) long with a static pressure tap 5.1 cm. (2 in.) from one end. See Figure B3. The tube end nearest the pressure tap is flanged to about 10.8 cm. (4¼ in.) OD with a male thread of the same size as the inlet end of the high-volume air sampler. A single metal plate 9.2 cm. (3⅝ in.) in diameter and 0.24 cm. (1/16 in.) thick with a central orifice 2.9 cm. (1⅛ in.) in diameter is held in place at the air inlet end with a female threaded ring. The other end of the tube is flanged to

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*Reproduced from Code of Federal Regulation 40, Part 50.11, Appendix B, July 1, 1975, Pages 12-16.

series of loadplates, one at a time, between the calibration unit and the primary standard. Placing the orifice before the inlet reduces the pressure at the inlet of the primary standard below atmospheric; therefore, a correction must be made for the increase in volume caused by this decreased inlet pressure. Attach one end of a second differential manometer to an inlet pressure tap of the primary standard and leave the other open to the atmosphere. During each of the constant airflow measurements made above, measure the true inlet pressure of the primary standard with this second differential manometer. Measure atmospheric pressure and temperature. Correct the measured air volume to true air volume as directed in 9.1.1, then obtain true airflow rate, Q, as directed in 9.1.3. Plot the differential manometer readings of the orifice unit versus Q.

8.1.2 *High-Volume Sampler.* Assemble a high-volume sampler with a clean filter in place and run for at least 5 minutes. Attach a rotameter, read the ball, adjust so that the ball reads 65, and seal the adjusting mechanism so that it cannot be changed easily. Shut off motor, remove the filter, and attach the orifice calibration unit in its place. Operate the high-volume sampler at a series of different, but constant, airflows (usually six). Record the reading of the differential manometer on the orifice calibration unit, and record the readings of the rotameter at each flow. Measure atmospheric pressure and temperature. Convert the differential manometer reading to m^3/min., Q, then plot rotameter reading versus Q.

8.1.3 *Correction for Differences in Pressure or Temperature.* See Addendum B.

9. *Calculations.*

9.1 *Calibration of Orifice.*

9.1.1 *True Air Volume.* Calculate the air volume measured by the positive displacement primary standard.

$$V_a = \frac{(P_a - P_m)}{P_a}(V_M)$$

V_a = True air volume at atmospheric pressure, m^3

P_a = Barometric pressure, mm. Hg.

P_m = Pressure drop at inlet of primary standard, mm. Hg.

V_M = Volume measured by primary standard, m^3

9.1.2 *Conversion Factors.*

Inches Hg. × 25.4 = mm. Hg.

Inches water × 73.48 × 10^{-4} = inches Hg.

Cubic feet air × 0.0284 = cubic meters air.

9.1.3 *True Airflow Rate.*

$$Q = \frac{V_a}{T}$$

Q = Flow rate, m^3/min.

T = Time of flow, min.

9.2 *Sample Volume.*

9.2.1 *Volume Conversion.* Convert the initial and final rotameter readings to true airflow rate, Q, using calibration curve of 8.1.2.

9.2.2 *Calculate volume of air sampled*

$$* \quad V = \frac{Q_i Q_f}{2} \times T$$

V = Air volume sampled, m^3

Q_i = Initial airflow rate, m^3/min.

Q_f = Final airflow rate, m^3/min.

T = Sampling time, min.

9.3 *Calculate mass concentration of suspended particulates*

$$S.P. = \frac{(W_f - W_i) \times 10^6}{V}$$

S.P. = Mass concentration of suspended particulates, $\mu g/m^3$

W_i = Initial weight of filter, g.

W_f = Final weight of filter, g.

V = Air volume sampled, m^3

10^6 = Conversion of g. to μg.

10. *References.*

(1) Robson, C. D., and Foster, K. E., "Evaluation of Air Particulate Sampling Equipment", *Am. Ind. Hyg. Assoc. J.* 24, 404 (1962).

(2) Tierney, G. P., and Conner, W. D., "Hygroscopic Effects on Weight Determinations of Particulates Collected on Glass-Fiber Filters", *Am. Ind. Hyg. Assoc. J.* 28, 363 (1967).

(3) Unpublished data based on a collaborative test involving 12 participants, conducted under the direction of the Methods Standardization Services Section of the National Air Pollution Control Administration, October, 1970.

(4) Harrison, W. K., Nader, J. S., and Fugman, P. S., "Constant Flow Regulators for High-Volume Air Sampler", *Am. Ind. Hyg. Assoc. J.* 21, 114–120 (1960).

(5) Pate, J. B., and Tabor, E. C., "Analytical Aspects of the Use of Glass-Fiber Filters for the Collection and Analysis of Atmospheric Particulate Matter", *Am. Ind. Hyg. Assoc. J.* 23, 144–150 (1962).

ADDENDA

A. *Alternative Equipment.*

A modification of the high-volume sampler incorporating a method for recording the actual airflow over the entire sampling period has been described, and is acceptable for measuring the concentration of suspended particulates (Henderson, J. S., Eighth Conference on Methods in Air Pollution and Industrial Hygiene Studies, 1967, Oakland,

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*This equation should read $V = \frac{(Q_i + Q_f)}{2} \times T$

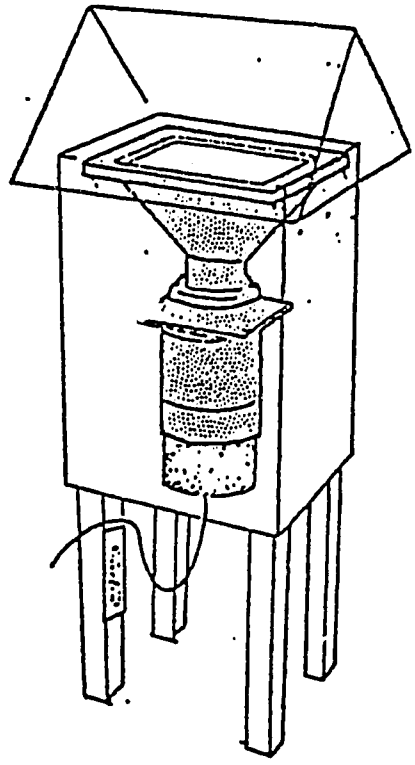

Figure B2. Assembled sampler and shelter.

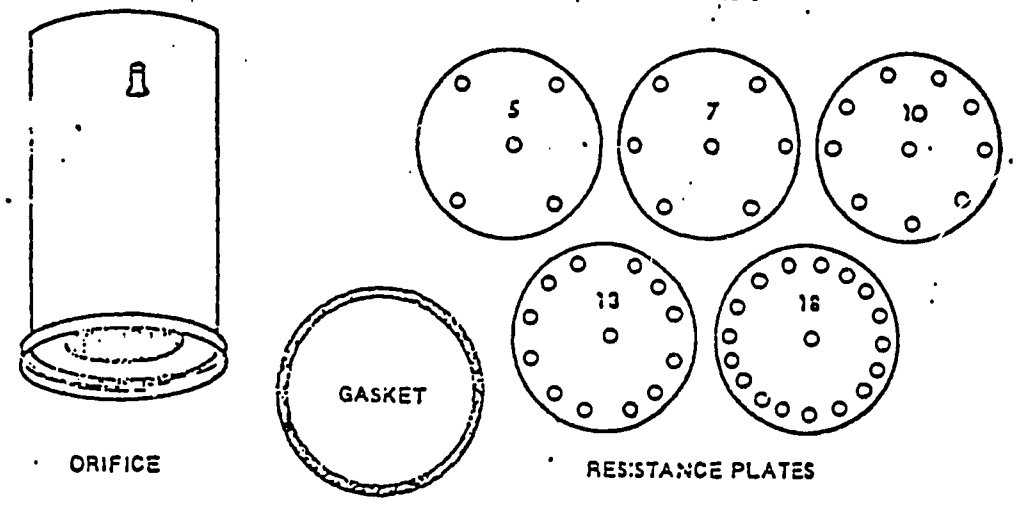

Figure B3. Orifice calibration unit.

APPENDIX 3

REFERENCE METHOD FOR DETERMINATION OF SULFUR DIOXIDE IN THE ATMOSPHERE (PARAROSANILINE METHOD)

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REFERENCE METHOD *

—REFERENCE METHOD FOR THE DETERMINATION OF SULFUR DIOXIDE IN THE ATMOSPHERE (PARAROSANILINE METHOD)

1. *Principle and Applicability.* 1.1 Sulfur dioxide is absorbed from air in a solution of potassium tetrachloromercurate (TCM). A dichlorosulfitomercurate complex, which resists oxidation by the oxygen in the air, is formed (*1, 2*). Once formed, this complex is stable to strong oxidants (e.g., ozone, oxides of nitrogen). The complex is reacted with pararosaniline and formaldehyde to form intensely colored pararosaniline methyl sulfonic acid (*3*). The absorbance of the solution is measured spectrophotometrically.

1.2 The method is applicable to the measurement of sulfur dioxide in ambient air using sampling periods up to 24 hours.

2. *Range and Sensitivity.* 2.1 Concentrations of sulfur dioxide in the range of 25 to 1,050 $\mu g/m.^3$ (0.01 to 0.40 p.p.m.) can be measured under the conditions given. One can measure concentrations below 25 $\mu g./m.^3$ by sampling larger volumes of air, but only if the absorption efficiency of the particular system is first determined. Higher concentrations can be analyzed by using smaller gas samples, a larger collection volume, or a suitable aliquot of the collected sample. Beer's Law is followed through the working range from 0.03 to 1.0 absorbance units (0.8 to 27 $\mu g.$ of sulfite ion in 25 ml. final solution computed as SO_2).

2.2 The lower limit of detection of sulfur dioxide in 10 ml. TCM is 0.75 $\mu g.$ (based on twice the standard deviation) representing a concentration of 25 $\mu g./m.^3 SO_2$ (0.01 p.p.m.) in an air sample of 30 liters.

3. *Interferences.* 3.1 The effects of the principal known interferences have been minimized or eliminated. Interferences by oxides of nitrogen are eliminated by sulfamic acid (*4, 5*), ozone by time-delay (*6*), and heavy metals by EDTA (ethylenediaminetetraacetic acid, disodium salt) and phosphoric acid (*4, 6*). At least 60 $\mu g.$ Fe (III), 10 $\mu g.$ Mn (II), and 10 $\mu g.$ Cr(III) in 10 ml. absorbing reagent can be tolerated in the procedure. No significant interference was found with 10 $\mu g.$ Cu (II) and 22 $\mu g.$ V(V).

4. *Precision, Accuracy, and Stability.* 4.1 Relative standard deviation at the 95 percent confidence level is 4.6 percent for the analytical procedure using standard samples. (*5*)

4.2 After sample collection the solutions are relatively stable. At 22° C. losses of sulfur dioxide occur at the rate of 1 percent per day. When samples are stored at 5° C. for 30 days, no detectable losses of sulfur dioxide occur. The presence of EDTA enhances the stability of SO_2 in solution, and the rate of decay is independent of the concentration of SO_2. (*7*)

5. *Apparatus.*

5.1 *Sampling.*

5.1.1 *Absorber.* Absorbers normally used in air pollution sampling are acceptable for concentrations above 25 $\mu g./m.^3$ (0.01 p.p.m.). An all-glass midget impinger, as shown in Figure A1, is recommended for 30-minute and 1-hour samples.

For 24-hour sampling, assemble an absorber from the following parts:

Polypropylene 2-port tube closures, special manufacture (available from Bel-Art Products, Pequannock, N.J.).

Glass impingers, 6 mm. tubing, 6 inches long, one end drawn to small diameter such that No. 79 jewelers drill will pass through, but No. 78 jewelers drill will not. (Other end fire polished.)

Polypropylene tubes, 164 by 32 mm. (Nalgene or equal).

5.1.2 *Pump.* Capable of maintaining an air pressure differential greater than 0.7 atmosphere at the desired flow rate.

5.1.3 *Air Flowmeter or Critical Orifice.* A calibrated rotameter or critical orifice capable of measuring air flow within ±2 percent. For 30-minute sampling, a 22-gauge hypodermic needle 1 inch long may be used as a critical orifice to give a flow of about 1 liter/minute. For 1-hour sampling, a 23-gauge hypodermic needle five-eighths of an inch long may be used as a critical orifice to give a flow of about 0.5 liter/minute. For 24-hour sampling, a 27-gauge hypodermic needle three-eighths of an inch long may be used to give a flow of about 0.2 liter/minute. Use a membrane filter to protect the needle (Figure A1a).

5.2 *Analysis.*

5.2.1. *Spectrophotometer.* Suitable for measurement of absorbance at 548 nm. with an effective spectral band width of less than 15 nm. Reagent blank problems may occur with spectrophotometers having greater spectral band width. The wavelength calibration of the instrument should be verified. If transmittance is measured, this can be converted to absorbance:

$$A = \log_{10}(1/T)$$

6. *Reagents.*

6.1 *Sampling.*

6.1.1 *Distilled water.* Must be free from oxidants.

6.1.2 *Absorbing Reagent [0.04 M Potassium Tetrachloromercurate (TCM)].* Dissolve 10.86 g. mercuric chloride, 0.066 g. EDTA (ethylenediaminetetraacetic acid, disodium salt), and 6.0 g. potassium chloride in water and bring to mark in a 1,000-ml. volumetric flask. (Caution: highly poisonous. If spilled on skin, flush off with water immediately). The pH of this reagent should be approximately 4.0, but it has been shown that there is no appreciable difference in collection efficiency over the range of pH 5 to pH 3.(*7*) The absorbing reagent is normally stable for 6 months. If a precipitate forms, discard the reagent.

*Taken from CFR 40, Protection of the Environment, Part 50.11, July 1, 1975.

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ing to the prescribed analytical procedure and to the specified concentration of the dye; (3) the calibration curve (Section 8.2.1) should have a slope of 0.030±0.002 absorbance units/μg. SO_2 at this path length when the dye is pure and the sulfite solution is properly standardized.

6.2.10.2 *Preparation of Stock Solution.* A specially purified (99–100 percent pure) solution of pararosaniline, which meets the above specifications, is commercially available in the required 0.20 percent concentration (Harleco*). Alternatively, the dye may be purified, a stock solution prepared and then assayed according to the procedure of Scaringelli, et al. (4)

6.2.11 *Pararosaniline Reagent.* To a 250-ml. volumetric flask, add 20 ml. stock pararosaniline solution. Add an additional 0.2 ml. stock solution for each percent the stock assays below 100 percent. Then add 25 ml. 3 M phosphoric acid and dilute to volume with distilled water. This reagent is stable for at least 9 months.

7. *Procedure.*

7.1 *Sampling.* Procedures are described for short-term (30 minutes and 1 hour) and for long-term (24 hours) sampling. One can select different combinations of sampling rate and time to meet special needs. Sample volumes should be adjusted, so that linearity is maintained between absorbance and concentration over the dynamic range.

7.1.1 *30-Minute and 1-Hour Samplings.* Insert a midget impinger into the sampling system, Figure A1. Add 10 ml. TCM solution to the impinger. Collect sample at 1 liter/minute for 30 minutes, or at 0.5 liter/minute for 1 hour, using either a rotameter, as shown in Figure A1, or a critical orifice, as shown in Figure A1a, to control flow. Shield the absorbing reagent from direct sunlight during and after sampling by covering the impinger with aluminum foil, to prevent deterioration. Determine the volume of air sampled by multiplying the flow rate by the time in minutes and record the atmospheric pressure and temperature. Remove and stopper the impinger. If the sample must be stored for more than a day before analysis, keep it at 5° C. in a refrigerator (see 4.2).

7.1.2 *24-Hour Sampling.* Place 50 ml. TCM solution in a large absorber and collect the sample at 0.2 liter/minute for 24 hours from midnight to midnight. Make sure no entrainment of solution results with the impinger. During collection and storage protect from direct sunlight. Determine the total air volume by multiplying the air flow rate by the time in minutes. The correction of 24-hour measurements for temperature and pressure is extremely difficult and is not ordinarily done. However, the accuracy of the measurement will be improved if meaningful corrections can be applied. If storage is necessary, refrigerate at 5° C. (see 4.2).

7.2 *Analysis.*

7.2.1 *Sample Preparation.* After collection, if a precipitate is observed in the sample, remove it by centrifugation.

7.2.1.1 *30-Minute and 1-Hour Samples.* Transfer the sample quantitatively to a 25-ml. volumetric flask; use about 5 ml. distilled water for rinsing. Delay analyses for 20 minutes to allow any ozone to decompose.

7.2.1.2 *24-Hour Sample.* Dilute the entire sample to 50 ml. with absorbing solution. Pipet 5 ml. of the sample into a 25-ml. volumetric flask for chemical analyses. Bring volume to 10 ml. with absorbing reagent. Delay analyses for 20 minutes to allow any ozone to decompose.

7.2.2 *Determination.* For each set of determinations prepare a reagent blank by adding 10 ml. unexposed TCM solution to a 25-ml. volumetric flask. Prepare a control solution by adding 2 ml. of working sulfite-TCM solution and 8 ml. TCM solution to a 25-ml. volumetric flask. To each flask containing either sample, control solution, or reagent blank, add 1 ml. 0.6 percent sulfamic acid and allow to react 10 minutes to destroy the nitrite from oxides of nitrogen. Accurately pipet in 2 ml. 0.2 percent formaldehyde solution, then 5 ml. pararosaniline solution. Start a laboratory timer that has been set for 30 minutes. Bring all flasks to volume with freshly boiled and cooled distilled water and mix thoroughly. After 30 minutes and before 60 minutes, determine the absorbances of the sample (denote as A), reagent blank (denote as A_o) and the control solution at 548 nm. using 1-cm. optical path length cells. Use distilled water, not the reagent blank, as the reference. (Note! This is important because of the color sensitivity of the reagent blank to temperature changes which can be induced in the cell compartment of a spectrophotometer.) Do not allow the colored solution to stand in the absorbance cells, because a film of dye may be deposited. Clean cells with alcohol after use. If the temperature of the determinations does not differ by more than 2° C. from the calibration temperature (8.2), the reagent blank should be within 0.03 absorbance unit of the y-intercept of the calibration curve (8.2). If the reagent blank differs by more than 0.03 absorbance unit from that found in the calibration curve, prepare a new curve.

7.2.3 *Absorbance Range.* If the absorbance of the sample solution ranges between 1.0 and 2.0, the sample can be diluted 1:1 with a portion of the reagent blank and read within a few minutes. Solutions with higher absorbance can be diluted up to sixfold with

*Hartmen-Leddon, 60th and Woodland Avenue, Philadelphia, PA 19143.

9.2.1 When sulfite solutions are used to prepare calibration curves, compute the concentration of sulfur dioxide in the sample:

$$\mu g.\ SO_2/m^3 = \frac{(A - A_o)\ (10^3)\ (B_s)}{V_s} \times D$$

A = Sample absorbance.

A_o = Reagent blank absorbance.

10^3 = Conversion of liters to cubic meters.

V_s = The sample corrected to 25° C. and 760 mm. Hg. liters.

B_s = Calibration factor, $\mu g./$absorbance unit.

D = Dilution factor.

For 30-minute and 1-hour samples, D = 1.

For 24-hour samples, D = 10.

9.2.2 When SO_2 gas standard atmospheres are used to prepare calibration curves, compute the sulfur dioxide in the sample by the following formula:

$$SO_2,\ \mu g./m.^3 = (A - A_o) \times B_g$$

A = Sample absorbance.

Ao = Reagent blank absorbance.

B_g = (See 8.2.2.3).

9.2.3 *Conversion of $\mu g./m.^3$ to p.p.m.* = If desired, the concentration of sulfur dioxide may be calculated as p.p.m. SO_2 at reference conditions as follows:

$$p.p.m.\ SO_2 = \mu g.\ SO_2/m.^3 \times 3.82 \times 10^{-4}$$

10. *References.*

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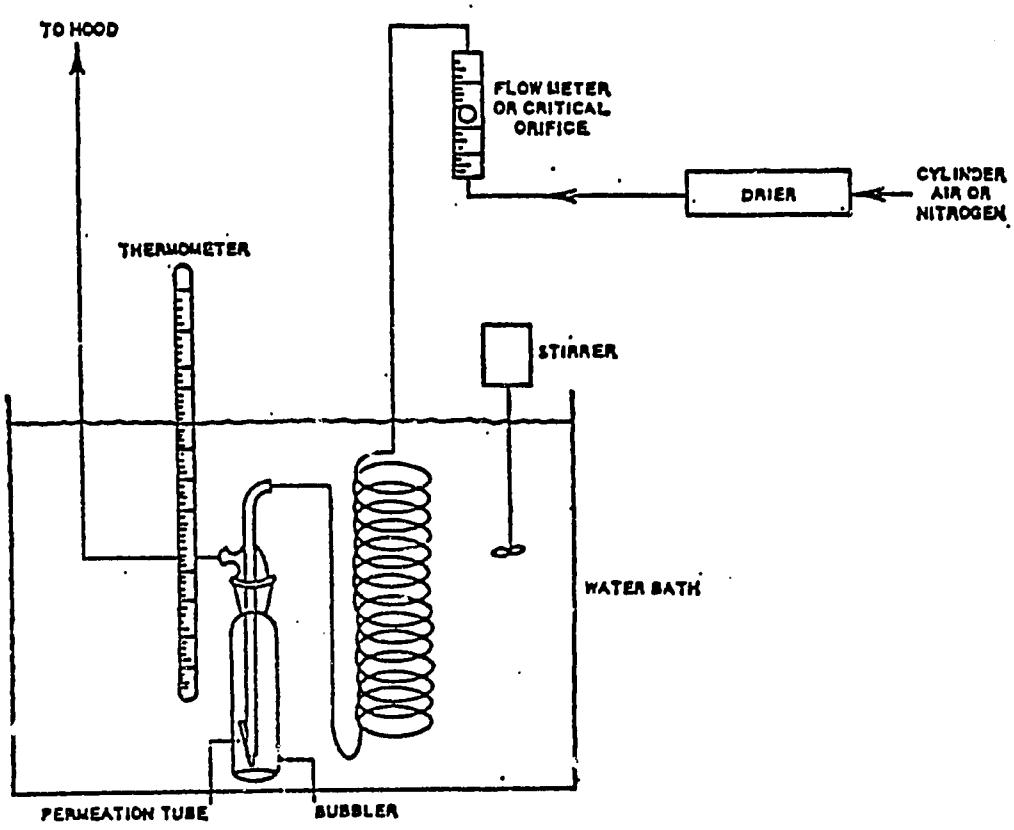

Figure A2. Apparatus for gravimetric calibration and field use.

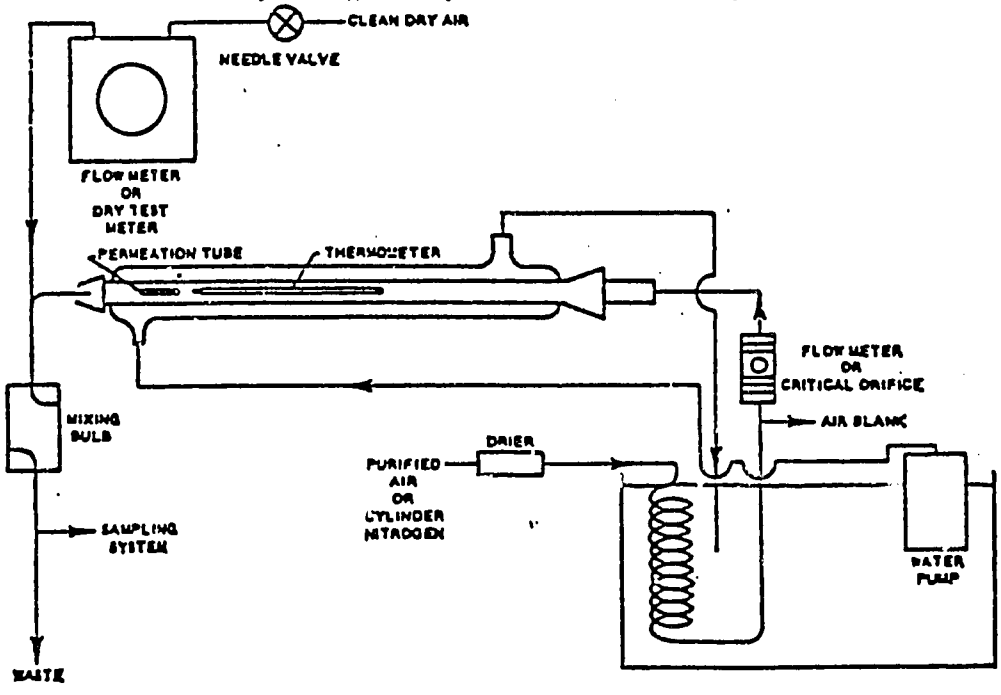

Figure A3. Permeation tube schematic for laboratory use.

APPENDIX 4

THREE POLLUTANT GAS SAMPLER

Reliable Accurate Control

BULLETIN 2441

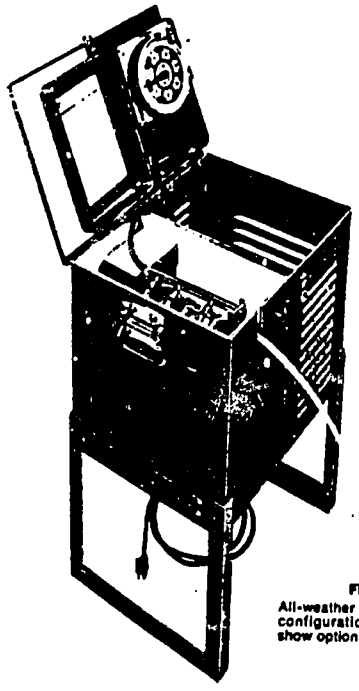

FIGURE 1
All-weather shelter in operating configuration (top opened to show optional timer).

versatile 3-GAS SAMPLER

designed to sample up to three different pollutant gases simultaneously, this unit features a unique thermoelectric system to assure maximum accuracy for SO_2 sampling

• features

- Meets or exceeds EPA specifications for sampling SO_2 & NO_2 in ambient air
- Thermoelectric cooling-heating system maintains SO_2 reagent between 7 & 17°C for optimum sample stability at ambient temps from −25 to 50°C
- Both all-weather shelter & indoor models are portable, easy-to-operate
- All-weather unit can be equipped with timing mechanisms (optional)
- Critical orifices provide 200 ml/min flow rate (nominal) through system
- All orifices are protected by inline filters & demistors to prevent clogging & flow reduction
- Sampling train compartment has an adjustable heater & fan for non-thermoelectrically-controlled bubblers
- Bubblers & closures supplied in colors; demistors-traps in natural plastic
- Modification kit is available to adapt existing RAC 5-Gas Samplers (outdoor models) to use thermoelectric module for SO_2 sampling

• application

The RAC 3-Gas Collecting Sampler is a wet-chemical system that will sample ambient air for any pollutant gas for which there is a suitable reagent (absorbing solution). It tests for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrogen sulfide (H_2S), ammonia (NH_3), aliphatic aldehydes (R-CHO), and other gases reactive to specific aqueous reagents. This system can be used virtually anywhere that line power is available to serve widely diversified gas sampling requirements.

In its basic configuration, the RAC 3-Gas system is designed to collect samples of SO_2, NO_2, and a third (optional) gas simultaneously. Modular components permit easy changes in sampling train configuration — except for the SO_2 arrangement (Station I)—to meet varying sampling needs.

Maximum SO_2 Sampling Accuracy

Recent tests performed by the Environmental Protection Agency (EPA) revealed that the accuracy of established wet-chemistry SO_2 sampling procedures is adversely affected by high ambient temperatures. At 50°C (122°F), for example, about 75% of the SO_2 in a collected or stored sample will be lost because of thermal instability within a 24-hour period. Sample degradation begins in the 20°C (68°F) range, with an initial loss factor of approximately 0.9% in 24 hours, and progresses at an increasing rate as the ambient temperature rises.

The RAC 3-Gas design eliminates this problem in SO_2 sampling. It features a rugged solid-state thermoelectric (Peltier Effect) cooling-heating system (Patent Pending) that maintains the temperature of the SO_2 bubbler and reagent between 7 and 17°C (44.6 and 62.6°F) in an ambient temperature range from −25 to 50°C (−13 to 122°F). As a result, all the SO_2 collected during a sampling cycle is preserved for optimum accuracy of sample evaluation by standardized wet chemistry and spectrophotometric procedures. This exclusive feature is another pioneering "first" in air pollution sampling equipment developed by Research Appliance Company.

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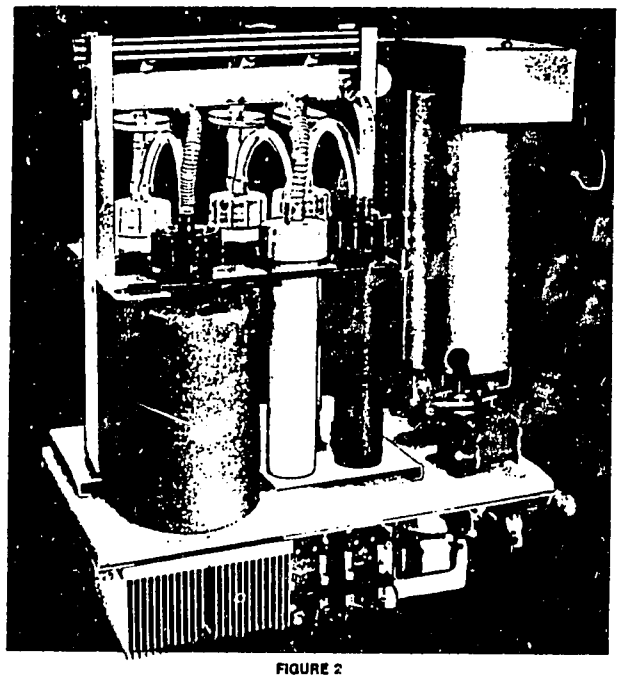

FIGURE 2
Sampling and temperature-regulating modules in operating position. Temperature of SO_2 bubbler (in insulating jacket) is controlled solely by a thermoelectric cooling-heating system. Heater and circulating fan assembly, at right, maintains temperature in insulated compartment above 16°C for reagents in other bubblers, but does not affect SO_2 bubbler.

• design

The RAC 3-Gas sampling system is supplied in a portable all-weather shelter model for outdoor use and in a smaller, lighter weight, steel case enclosed indoor model. Both are furnished complete and ready-to-operate. In addition, a modification kit is offered to adapt existing RAC 5-Gas Samplers (shelter models only) to use the new thermoelectric cooling-heating system for SO_2 sampling.

All-Weather Shelter Model

This self-contained design includes a heavy-gage steel cabinet with a hinged, lockable top member, two separate compartments, and a weather-resistant baked enamel finish. The preassembled complete sampling train, the thermoelectric system, and a thermostatically-controlled heater assembly are installed in an insulated compartment; the system's vacuum pump, vacuum gage, and electrical junction box are installed in the second compartment, which has louvers on three sides for heat dissipation. A 3-wire power cord is supplied as standard.

SAMPLING TRAIN—The RAC gas sampling train assembly includes a polypropylene inlet tube with a conical rainshield and an aluminum rack containing a 3-branch glass inlet manifold, 3 polypropylene 100 ml bubblers with interchangeable closures*, 3 polypropylene demistor-entrainment traps, 3 critical/limiting orifices, a 3-branch exhaust manifold, and all necessary connecting tubing. The sampling rack is positioned on a base module that supports the thermoelectric device for the SO_2 bubbler and the nonrelated compartment heater and blower assembly. The complete sampling module is easily removed for filling, cleaning, or change in configuration (except for the SO_2 arrangement). The base module also is easy to remove for periodic inspection or servicing.

Threaded closures for the polypropylene bubbler tubes are a 2-hole inlet-outlet unit used for sampling operations and a solid leak-tight cap used to transport bubblers containing reagents. The 100 ml bubblers and both types of closures are supplied in red, yellow, and blue colors, one complete set in each color. Their related demistor-trap units are furnished only in natural plastic.

The bubblers in Station I (SO_2 sampling) and Station III (third gas sampling) contain orifice-type 0.35 mm glass bubbler tubes. The unit in Station II (NO_2 sampling) has a fritted glass dispersing element (70 to 100 μ).

TEMPERATURE CONTROL—The SO_2 bubbler is encased in an insulating jacket and its temperature is controlled between 7 and 17°C solely by the thermoelectric cooling-heating system. To prevent reagents in the other two bubblers from freezing during cold weather, a constant (variable) temperature above 16°C (60.6°F) is maintained in the insulated compartment by the integral heater, which does not affect the temperature of the specially insulated SO_2 bubbler.

The newly-developed thermoelectric system uses a finned heat sink and blower combination for efficient heat transfer, and is protected by a thermal cutout on the heat sink as well as two fuses in the electrical circuit.

FLOW-REGULATING ORIFICES — The critical/limiting orifices can be either the stainless steel needle type or precision-bore glass tubing encased in Tygon plastic tubing. Both types provide a 200 ml/min flow rate (approx) to all bubblers, and are easily cleaned in small RAC ultrasonic baths.

DETACHABLE LEGS — The all-weather shelter model has sturdy angle-iron legs that can be attached flush with the cabinet for carrying/transporting. The legs are securely attached in either the extended or retracted position by rust-resistant bolts threaded into captive nuts.

TIMING MECHANISMS — To meet a variety of sampling requirements, three different types of timing mechanisms can be supplied with the RAC 3-Gas all-weather shelter model: a 24-hour timer, a 7-day skip timer, or a 1-out-of-6 days timer. All timers are optional accessories.

Indoor Model

This unit is comprised of an insulated, louvered, steel carrying case, an external vacuum pump with gage, and a 3-wire power cord. It uses the same pump, complete sampling train, and base module as the shelter model, and provides the same versatile sampling

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capabilities for indoor applications. If desired, the indoor configuration can be used to sample outdoor air by passing the inlet tube and rainshield through any convenient structural opening or by connecting them to an air inlet duct. The sampling case and pump should be shielded from inclement weather conditions at all times.

Modification Kit

All-weather shelter models of the **RAC 5-Gas Collecting Sampler** can be adapted to use the thermoelectric cooling-heating system for SO_2 by means of a packaged modification kit. The kit includes a steel cabinet of modified design, a new bubbler rack and manifolds, the new solid-state thermoelectric system, and the adjustable compartment heater assembly. Since all other components of a 5-Gas Sampler can be interchanged without alteration, the kit does *not* include vacuum pump, bubblers, demistors-traps, orifices, inlet tube and rainshield, connecting lines, or power cord. If any of these standard components are required, they can be ordered as replacement parts.

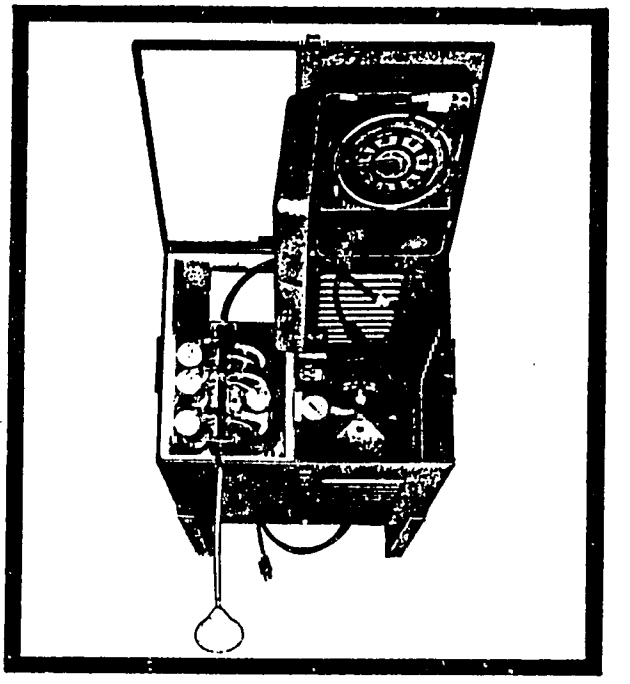

FIGURE 3
Arrangement of 3-Gas system components in all-weather shelter. A 24-hour or 1-out-of-6 days timer mechanism can be used in place of the 7-day timer shown. Timers are optional.

• operation

***NOTE:** When sampling for SO_2, a membrane-type particulate filter should NOT be used between the air inlet tube and manifold because it may absorb a major portion of the SO_2 in the sample stream.*

In operation, the vacuum pump draws ambient air in through the conical rainshield and inlet tube. (Rainshield is inverted to prevent precipitation from entering the sampling train.) The inlet manifold divides the air stream into equal volumes that flow through Teflon tubing to the bubblers. Each bubbler has a 2-hole cap with a standard glass bubbler tube, either constricted or fritted, on the inlet port (see details under SAMPLING TRAIN). The sample air passes through these tubes into 50 ml of reagent contained in each bubbler.

After bubbling through the reagent, the air exhausts through Tygon tubing connected to the outlet port in the cap. Each sample stream then passes through another polypropylene bubbler containing a demistor followed by a membrane filter. This dual-trap arrangement protects the critical orifices from moisture or other entrainments, and helps to maintain continuous full-flow operation for optimum sampling efficiency. The scrubbed air streams then flow through the critical orifices to the exhaust manifold and are discharged through the pump. ***NOTE:** The membrane filters and the demistors-traps should be replaced periodically in accordance with the procedures being used.*

In this instrument, contaminate gas samples contact only polypropylene, Teflon, or glass before entering the absorbing reagents. This design concept provides for optimum sample collection. All materials in contact with the sample stream are widely recognized for their noncontaminating characteristics when used in probes for a broad range of air pollutants.

After a sampling cycle is completed, the sampling train assembly is removed from the shelter (or carrying case). The reagent tubes are removed from the rack, and the 2-hole closures are replaced with solid, leak-tight, threaded caps. These then are taken to a laboratory for analysis of contents according to appropriate procedures. Tubes containing thermally unstable gas samples, such as SO_2, should be transported in refrigerated containers.

• specifications

Vacuum Pump
¼ hp, 0.5 cfm free-flow, continuous duty, overload protected

Electrical
SHELTER MODEL:
Std: 115 volts, 60 Hz, 3.7 amp
Opt: 220 volts, 50/60 Hz, 1.9 amp
INDOOR MODEL:
Std: 115 volts, 60 Hz, 1.9 amp
Opt: 220 volts, 50/60 Hz, 1.0 amp

Dimensions
SHELTER MODEL:
69.9 cm (27½") H x 45.7 cm (18") W x 35.7 cm (14⅛") D w/legs extended: 39.2 cm (15¾") H w/legs raised.
INDOOR MODEL:
39.2 cm (15¾") H x 33.7 cm (13¼") W x 21 cm (8¼") D

Weights
SHELTER MODEL:
15 kg (33 lb) including pump (without timer installed)
INDOOR MODEL:
10.9 kg (24 lb) without pump
VACUUM PUMP: 2.7 kg (6 lb)
24-HOUR TIMER: 1.4 kg (3 lb)
7-DAY TIMER: 2.7 kg (6 lb)

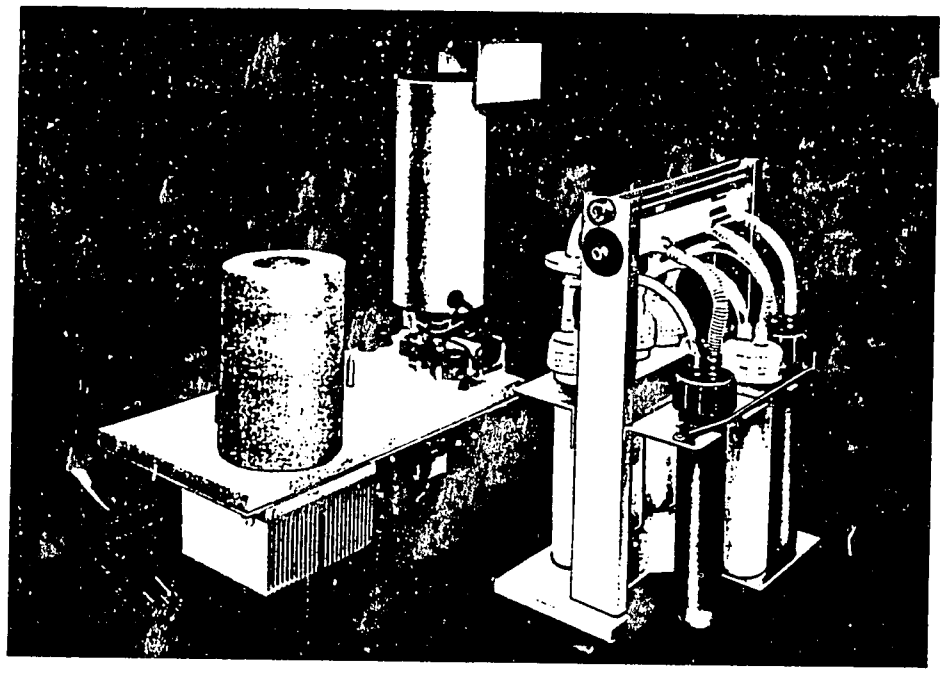

FIGURE 4
Sampling train assembly is easily disconnected and removed from shelter (or carrying case) for filling and cleaning. Base module also is removable for periodic inspection or servicing.

• ordering information

Both the all-weather shelter and indoor models of the RAC 3-Gas Collecting Sampler are shipped complete and ready-to-operate. The specific models include the components listed in the Design section of this bulletin. In addition, a pack of critical/limiting orifices (3) and a pack of membrane filters and backup discs (3 each) are supplied with each instrument.

Specify the model, voltage, and power line frequency desired—plus any optional timer mechanism — by full name and catalog number. Unit prices and catalog numbers for the individual system components are furnished on separate sheets.

RAC 3-Gas Collecting Sampler, All-Weather Shelter Model, Complete:

With GLASS Orifices	CAT. #209068
With NEEDLE Orifices	CAT. #209069

RAC 3-Gas Collecting Sampler, Indoor Model, Complete:

With GLASS Orifices	CAT. #209071
With NEEDLE Orifices	CAT. #209072
RAC 24-Hour Timer	CAT. #992424
RAC 7-Day Skip Timer	CAT. #992425

• other sampling equipment

Research Appliance Company manufactures and supplies a wide range of precision instruments and systems designed for sampling/monitoring environmental air, water, and noise pollution. Write for descriptive literature, indicating the types of products on which information is desired.

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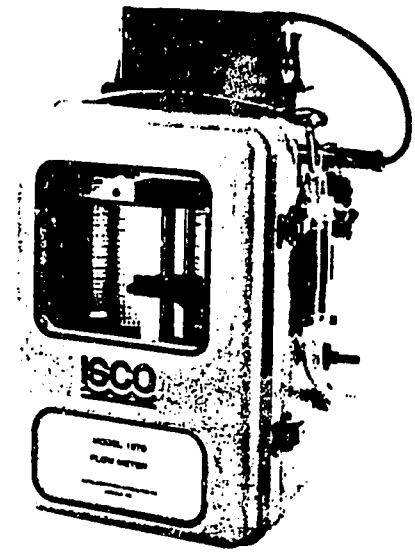
Appendix 5

Water Quality Monitoring Equipment

a. ISCO Model 1870 Recording Flowmeter

recording flow meters



ISCO integrating flow meters accurately measure and record open channel flow in manholes and streams, and in water, wastewater, and industrial plants. They are suitable for portable or stationary use, and can also trigger automatic samplers at intervals based on volume of passing fluid rather than time. Flow proportioned samples more closely represent the true composition of the stream, and decrease the risk of missing intermittent events such as dumping of individual tanks. Flow volumes over wide ranges can be preselected so that a sampler will be triggered as each volume passes. Most ISCO samplers additionally have flow multipliers which expand available flow volumes even further.

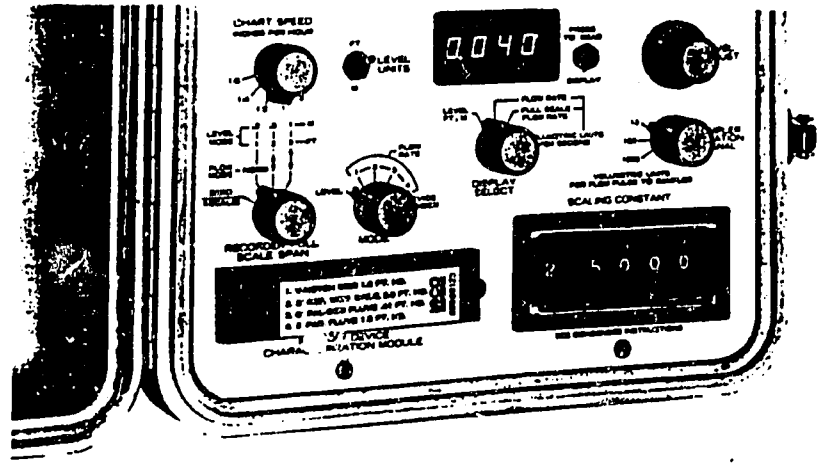
ISCO flow meters can be used in conjunction with a user-supplied primary device (flume or weir) having a know relationship between flow rate and water level or in certain other open channel applications where a primary device is not or cannot be installed. Upstream water height is measured and continuously indicated showing the actual water level, not just a percentage of maximum range. This value is electronically converted into an instantaneous flow rate which is then integrated with time to provide totalized flow.

ISCO flow meters have a six digit, resettable totalizer directly reading total flow in gallons, liters, or whatever unit has been selected. No correction tables or multiplication factors are necessary. The flow rate can be recorded on a built-in recorder in the Model 1870 or the signal from a Model 1530 or 1700 may be transmitted to an accessory strip chart recorder for a flow rate vs. time record. An accessory digital printer provides a permanent tape record of totalized flow at preselected time intervals, eliminating the manual integration necessary with conventional recorders

The optional, externally accessible Nicad battery will typically operate a Model 1870 recording flow meter for 72 hours per charge, a Model 1700 flow meter for 200 hours or a Model 1530 for 400 hours For extended remote operation, an external 12 volt automotive battery may be used A power converter replaces the

ISCO flow meters use proven methods to determine water level. The Models 1870 and 1700 have a submerged plastic tube which continuously emits bubbles just upstream from the primary device. As the water level fluctuates, pressure changes in the tubing are accurately measured with a sensitive electronic transducer. The Model 1530 flow meter detects head height changes with a float Both methods have demonstrated their reliability over many years' service

Level-to-flow rate conversion in the Model 1870 is accurately accomplished by the Primary Device Characterization Module, in which the level-flow rate relationship of the primary device has been digitally stored. Using the stored level-flow information, the flow meter's microprocessor-based circuitry converts the level signal from the transducer to a signal proportional to flow rate The Models 1530 and 1700 utilize information stored on an optically coded function generator disc to convert water level to flow rate. This system provides substantially superior accuracy, resolution, and versatility than can be obtained with cams, conventional PROM systems, or analog power function generators Only the microprocessor-based



model 1870

The Model 1870 Recording Flow Meter has established a new standard in open channel flow measuring ease, accuracy, and versatility. Even under ideal conditions, measuring flow in open channels is tough. The Model 1870 Recording Flow Meter makes the task of providing accurate, reliable flow data easier. It has the versatility necessary to accommodate changing conditions or situations and is suitable for a variety of open channel flow monitoring applications including:

- Inflow and infiltration studies
- Sewer flow measurement
- Industrial waste monitoring
- Wastewater treatment plant flow measurement
- Natural stream flow measurement
- Irrigation flow measurement
- Combined sewer overflow and bypass studies
- Flow proportional pacing of automatic samplers

The Model 1870 can be used in conjunction with weirs, flumes, or any other open channel flow situation for which a known relationship exists between level and flow rate. Liquid level is measured by the reliable, field-proven ISCO bubbler system. A small inside diameter tube is submerged in the primary device. Air, supplied by an internal compressor, is bubbled out of the tube at a constant rate, resulting in a pressure in the tube proportional to the level in the primary device. A transducer measures this pressure and converts it

Flow rate (or level) is recorded on a rugged, built-in strip chart recorder and total flow is displayed on a six digit resettable totalizer. Both the recorder and totalizer operate in terms of real volumetric units, which the operator selects. No multiplying factors or percentages of maximum flow are involved.

The reprogrammable plug-in Primary Device Characterization Module stores level-flow rate information on not just one, but on four different primary devices or other open channel flow situations, as specified by the user. The device to be used is selected by a front panel switch. Modules can be interchanged if flow through more than four different devices is to be monitored, and the modules are factory reprogrammable. Level measurement is also switch selectable.

Units of measurement are established by a pushbutton Scaling Constant switch. Any volumetric unit may be chosen, whether it's cubic feet, gallons, cubic meters, liters, or any other unit. Settings for the Scaling Constant switch are supplied on a data sheet which accompanies each characterization module.

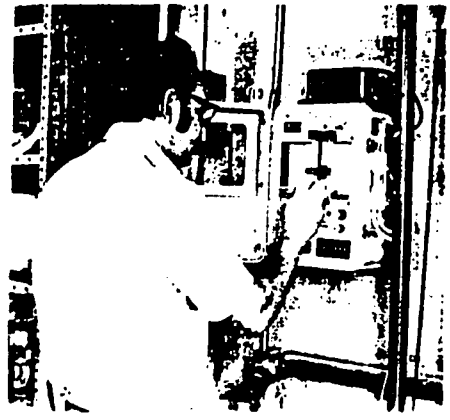
The flow meter records flow rate or level on a four inch wide by sixty-five foot long strip chart, capable of storing several months of data. A disposable, easily replaceable fiber tip pen is positioned by a lead screw mechanism, providing reliable, accurate operation. The microprocessor-based recorder circuitry handles the

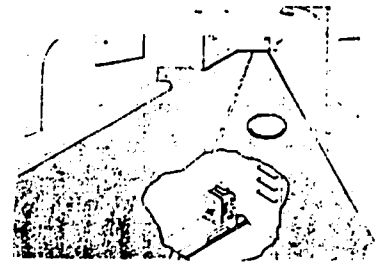
When recording flow rate, the recorder full scale span is automatically established according to the setting on the Scaling Constant switch, with an additional switch to provide two expanded scales, if necessary. When recording level, three full scale spans are available. The recorder also has an indicating over-ranging feature which automatically repositions the curve to the base line when full scale span is exceeded, preventing the accidental loss of data should much larger than expected flows occur.

A bright, four digit LED display is provided to indicate either liquid level, flow rate, or recorder full scale flow rate. Level can be indicated in either feet or meters, as selected by a front panel switch. The indicated level is easily adjusted to match actual liquid level by use of a lockable control, making initial calibration of level a simple matter.

A standard feature of the Model 1870 is a sampler initiation output signal which allows for flow proportional pacing of an automatic liquid sampler. An event mark will be placed on the chart record each time a sample is collected.

Operable on either 12 VDC battery power or 117 VAC line power, the Model 1870 is equally well suited for temporary or permanent installations. The optional, externally accessible Nicad battery will typically operate the flow meter for 72 hours per charge. For extended remote operation, an automotive battery cable is available, which permits the use of an external 12 volt automotive battery. An AC power converter replaces the battery when the instrument is to be used on line current. When the flow meter is used with an ISCO sampler, the sampler can supply power for both units.





The compact, self-contained Model 1870 is housed in a rugged, high impact strength ¼" thick structural foam case. Realistically designed to survive the harsh demands of open channel flow measurement sites, the flow meter is fully gasketed against moisture or accidental submersion, and features all stainless steel and anodized aluminum exterior hardware. Instrument electronics are based on highly reliable CMOS integrated circuitry with conservative design throughout.

Optionally available for use with the Model 1870 is the Model 1710 Digital Printer, described on page 10. The Model 1710 provides a digital printed record of incremental and total flow volumes at several switch selectable time intervals, plus month, day of the month, and time of day information. It provides the user with a dated hard copy record of incremental and total flow.

the model 1870 is easy to install, set up, and use

A typical open channel flow monitoring site is usually far from what would be considered ideal. Often remote, cramped, dark, damp and dirty, the average manhole is not a pleasant place for man or his machines. The Model 1870 was designed to minimize the operator's exposure to such environments. It is easy to install, setup, and use, even under the most difficult conditions.

The Model 1870 is compact, rugged, and easily transported. Since it is entirely self-contained, installation time is minimized. A built-in compressor supplies bubbler air; there is no need to worry about an external source of pressurized gas.

The flow meter can be conveniently mounted in a number of ways. It can simply be located on a flat

Because it is a bubbler, the Model 1870 does not have to be mounted over a stilling well, directly above the primary device, or even close to the flow stream, as with other types of flow meters. The flow meter itself can be installed at a convenient location and the bubble tube routed to the measuring point. A separation of up to 200 feet is possible. For example, the flow meter could be mounted at ground level for easy accessability. Then, the manhole would only need to be entered once, for bubble tube installation and calibration. The actual installation of the bubble tube in the flow stream is normally uncomplicated. Most flumes can be specified to include an integral bubble tube fitting.

Because of electronic calibration, the end of the bubble tube does not have to be installed at exactly the zero level of the weir or flume. Rather, it need only be installed so that the end is slightly lower than the minimum level expected. Then, using the flow meter's level adjustment control, the level indicated on the LED display is adjusted to match the actual level in the flow stream. The remainder of the set-up consists of adjusting other controls to obtain desired measuring conditions.

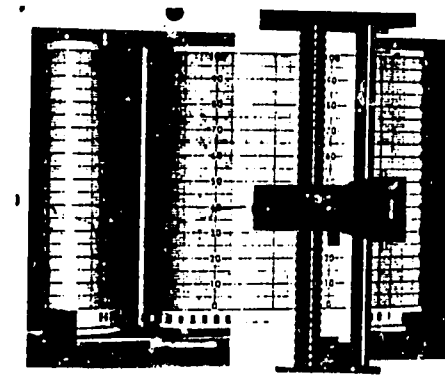
Once installed and set-up, the Model 1870 is easy to use and maintain. The flow rate chart and totalized flow are visible through a window, without opening the case. A digital display of liquid level is available at the push of a button, without disturbing the flow rate record. Installing a new chart is uncomplicated, and a single strip chart can last up to eight months. The flow meter was designed to have low power consumption, so battery life is long, a decided advantage for remote sites. Changing the external battery pack requires only a few seconds. The only routine maintenance required is the occasional changing of regenerable desiccant cartridges.

the model 1870 is accurate

Open channel flow monitoring is at best an inexact science. There can be significant errors associated with the primary measuring device (weir or flume) due to basic device inaccuracies, improper construction or installation, poor maintenance, etc. However, these potential primary device errors certainly do not justify similar errors in the secondary measuring instrumentation, as is the case with many flow meters. Any compromise in flow meter accuracy will add to the overall flow measurement system inaccuracy. The Model 1870 was designed using state of the art technology to provide extremely accurate level measuring and level-to-flow rate conversion systems.

sures the pressure in the bubble tube and hence the liquid level. This transducer is designed especially for the Model 1870 flow meter, with superior accuracy and temperature coefficient to provide accurate, stable level measurement. The bubbler system has none of the accuracy or long term stability limitations inherent in typical ultrasonic and certain other level measurement systems.

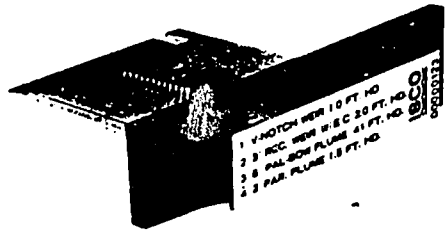
Level-to-flow rate conversion is accomplished through the use of a non-volatile integrated circuit memory device, a programmable read-only memory (PROM). The PROM stores a tabular set of actual level-flow rate values for a particular open channel flow situation (usually a weir or flume). Intermediate values are generated by a precise mathematical technique, made possible by the superior computing power of the microprocessor-based electronics of the flow meter. The result is a very accurate level-to-flow rate conversion system which also has excellent flow rate resolution throughout the entire level range. This conversion system is more accurate and versatile than typical mechanical cam or analog systems, and far more precise than PROM based systems not utilizing microprocessors.



Accurate presentation of flow data has been a problem with open channel flow meters. Many units have used two inch wide pressure writing strip chart recorders or circular chart recorders of questionable accuracy, resolution, and readibility. The Model 1870 overcomes these problems with a strip chart recorder designed and manufactured by ISCO specifically for the application of open channel flow monitoring. The entirely digital recorder uses a rugged, precision stainless steel lead

the model 1870 is versatile

To keep up with expanding capacities or changing flows, new or revised regulations, or to accommodate a variety of measuring sites, an open channel flow meter needs to be versatile. The Model 1870 was designed to have a high degree of built-in versatility.



The Primary Device Characterization Module, which contains the level-to-flow rate conversion PROM, has the capacity to store flow data on four different primary devices. At the time of order, the user can specify any combination of weirs, flumes, or other open channel flow situations for which the module is to be factory programmed. Then, by simply turning a switch, the Model 1870 can be set up to monitor flow through any one of the four devices

Since level-flow data is stored in the module digitally, any open channel flow situation for which a definable relationship exists between level and flow rate can be accommodated: standard and nonstandard weirs and flumes, gravity flow using the Manning formula, natural channels for which stage-discharge data exists, etc. This is not the case with flow meters using analog power function generator conversion systems. Such analog systems are normally limited to primary devices whose level-flow equation is of a certain form, usually single term power function. Analog converters can at best only approximate open channel flow situations which do not exactly fit the power function form (e.g., Palmer-Bowlus flumes, contracted rectangular weirs, the Manning formula, etc.). The entirely digital Model 1870 conversion system does not have this very restrictive limitation.

Additional plug-in Primary Device Characterization Modules are available, making the adaptability of the flow meter virtually limitless. Changing from one module to another is a simple matter, requiring less than thirty seconds to adapt the flow meter to four entirely different primary devices. As an added feature, the modules are factory reprogrammable.

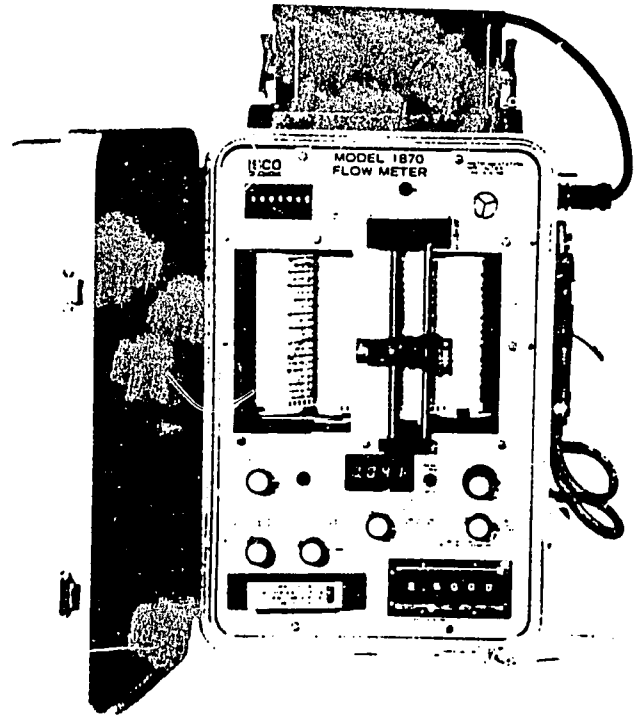
The Model 1870 can be set up to record flow rate and totalize flow in any volumetric unit desired. It can also be easily set up to record liquid level only, instead of flow rate. This may be useful when the level-flow relationship of the primary device is in question, or when only liquid level information is required

model 1870 flow meter specifications

Physical Size Height Width Depth	 15 1/4 in. (38.7 cm) 10 5/8 in. (27.0 cm) 10 3/8 in. (26.4 cm)
Weight	25 lbs (11.3 kg)
Liquid Level Range* English units Metric units	 0-3.0 ft. 0-1.0 m.
Level Measurement Accuracy	± 0.75% of full scale level
Recorder Resolution	Better than 0.1% of full scale span
Operating Modes	Level Flow rate through any one of four primary devices

Power Required Flow meter AC power converter	 12 volts DC 117 volts 50/60Hz (234 volts 50/60 Hz optional)
Nicad Battery Life	72 hr., average (after 18 hr. charge)
Recorder Full Scale Spans Level mode Flow mode	 1, 2, 3 ft, .2, .5, 1 m .01, .02, .05, .1, .2, .5, 1, 2, 5, 10 vol. units/sec.
Level-to-Flow Rate Conversion Precision	± 0.05% of recorder full scale span
Recorder Chart Speeds	1/8, 1/4, 1/2, 1, 2, 4, in./hr.
Chart Paper Width Length	 4 in., calibrated 65 ft.

* Special extended ranges available - consult factory



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ordering information

Model 1870 Recording Bubbler Flow Meter. With 1 Primary Device Characterization Module*, 2 rolls of chart paper, 2 pens, and 1/16" ID x 25' Teflon bubbler line. Without power source or sampler connect cable. Use Nicad battery, AC converter, or sampler power (60-1874-012 connect cable required) See below. 68-1870-001

Same as above, except with 1/8" ID x 50' vinyl bubbler line 68-1870-002

Extra Primary Device Characterization Module* 60-1874-011

Reprogram Primary Device Characterization Module* 68-1870-003

Suspension harness to hang flow meter from manhole rung, etc. .. 60-1704-016

Power Sources and Battery Chargers

Rechargeable Nicad battery. Without charger.

Same as used with ISCO samplers 60-1684-040

AC line power converter. Also may be used as battery charger. Same as used with standard pump ISCO samplers. 117V, 50/60 Hz 60-1684-046

Same as above, except 234V, 50/60 Hz. Also used on standard and superspeed pump ISCO samplers 60-1684-093

Automotive battery cable. Cable terminates in heavy duty battery clips and permits the use of an external 12 volt automotive battery for extended remote operation 60-1394-02

Extra Bubble Lines and Accessories

Extra bubble line, 1/16" ID x 25' Teflon 60-1871-031

Extra bubble line, 1/8" ID x 50' vinyl 60-1871-044

Extra bubble line, 1/8" ID x 100' vinyl 68-1700-303

4' stainless steel tube for use with 1/16" ID Teflon bubble line. Attaches to bubble line outlet 60-1704-018

4' stainless steel tube for use with 1/8" ID vinyl bubble line. Attaches to bubble line outlet 60-1871-041

Spare Chart Paper and Pens

Chart paper for recorder, 4" x 65' roll 250-0600-01

Recorder pen 250-0800-05

Flow Meter to Sampler Connections

Connect cable. Model 1870 Flow Meter to ISCO sampler, 22' long** 60-1874-012

Type E Interface. Converts Model 1870 sampler output signal to isolated contact closure (10 amp contact rating) for use with non-ISCO sampler requiring contact closure flow proportional input 60-1784-024

*Each module has four cells, and is programmed at the factory for the customer's choice of four particular primary devices (weirs, flumes, or other open channel flow situations). For each of the four devices (cells), specify: 1) type of device, 2) size (throat width, crest length, etc.), 3) the maximum head (any head up to 3 feet, or 1 meter). For a permanent installation where only one primary device is to be used, specify four different maximum heads.

Additional information is required for the following situations. For Palmer-Bowlus flumes, provide manufacturer's flow curves or data sheets. For gravity flow using the Manning formula specify: 1) configuration and dimensions of flow channel, 2) slope, and 3) roughness coefficient. For natural channels, provide stage-discharge data.

For V-notch weirs, Cipolletti weirs, rectangular weirs without end contractions, and Leopold-Lagco flumes, one cell in the module will accommodate all sizes of the same device at one maximum head. For example, one cell programmed for use with V-notch weirs will accommodate all angles (90°, 45°, 22½°, etc.) of V-notch weirs for a given maximum head (say, 2 feet). All other types of devices require a different cell in the module for each size device.

**Specify model and serial number of ISCO sampler if already in your possession.

open channel flow measurement handbook

by douglas m. grant

Anyone engaged in open channel flow measurement should have a copy of ISCO'S new data handbook. It contains over 80 pages of text material describing the various aspects of open channel flow measurement, the types of weirs and flumes used and their installation, and gravity flow in open channels. It also contains over 125 pages of weir and flume discharge tables. This is the most comprehensive handbook currently available on this subject. You may get your copy by sending your check for $7.95 to ISCO HANDBOOK, 3621 N.W. 35th Street, Lincoln, NE 68524. Payment must accompany the order.

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b. ISCO Model 1680 High Speed Sequential Sampler

model 1680 high speed sequential sampler

A Model 1680 sequential sampler can really simplify your pollution monitoring program. Reliable operation provides reproducible results you can trust; programming versatility insures against obsolescence due to changing regulations; and manhole-proof ruggedness withstands corrosive atmospheres, wear and tear, and frequent hosing or even total submersion. For taking a single composite sample, the standard 28 bottle sequential base section may be replaced with a base accommodating a single wide mouth container.

Typically, over one hundred full samples may be taken on an 18 hour charge of the removable Nicad or lead acid battery. An auxiliary battery within the controller maintains the logic for about eight hours in case of a power failure. While it will not power the pump, it accommodates power interruptions and battery changes without losing the program or time.

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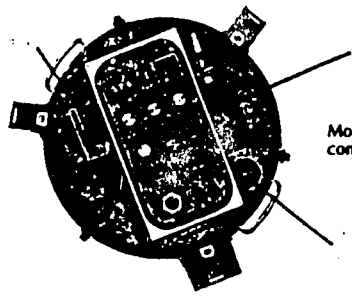
The one piece, clog-proof rotating funnel carries samples to the distributor plate without passing through any rotating seals or hard-to-clean tubing; the steep trough angle prevents sedimentation. Samples are conducted into individual bottles by a distributor plate. Both the funnel and distributor plate can be quickly removed for cleaning.

The base holds 28 bottles — four more than usual, to take the pressure off 24 hour servicing schedules. A large ice compartment is provided for cooling biological specimens. Its capacity is adequate to maintain samples at about 40°F below ambient for at least 12 hours, and 30°F below ambient for 24 hours. Construction is double-walled high impact plastic with foamed-in-place insulation having a nominal thickness of 1". Additional bases with covers and bottles may be obtained to retrieve samples from the field without interrupting collection. The cylindrical sample bottles are available in unbreakable, high density polyethylene (500 ml) or glass (400 ml). They are much easier to clean than wedge-shaped bottles since they have a wide mouth to admit a large brush and have no inaccessible corners. Polyethylene bottles can be washed in a dishwasher but not autoclaved. Glass bottles can be autoclaved and are also suitable for samples having organic components which may be absorbed by plastic bottles. All bottles are supplied with caps with polypropylene liners to insure safe handling. Teflon® lid liners are available separately for all ISCO bottles.

Outside dimensions are 21" high by 19½" diameter, and the weight is 40 lbs. with battery and polyethylene bottles.

Accessory composite base

The all-electronic controller provides collection intervals determined by the 1 to 999 minute quartz crystal timer or by any ISCO flow meter. Up to 999 signals from the flow meter can be combined for each sample. This greatly expands the range of flowstream volumes originally available in the flow meter, and simplifies interfacing with flow meters of other manufacture. Sampling normally commences immediately upon setup, but the initial sample can be delayed up to 999 minutes if desired. All values are entered with a pushbutton digital switch. An LED display shows the interval remaining before the next sample is taken.



Model 1680 controller

Maximum sample volume is 500 ml, selected with a 9 position switch. The switch scale indicates volumes for head heights to 21'. Another switch provides for the selection of six different suction line lengths. An optional multiplexer permits compositing 1, 2, 3, or 4 samples into each bottle, allowing a maximum of 112 samples to be placed into the 28 bottles. This provides more representative collection and reduces the danger of missing short term changes in stream composition. The multiplexer also can be used to distribute the sample over 1, 2, 3, or 4 bottles, permitting a larger sample volume or the use of several different preservatives. An automatic shutoff stops the sampling program after the last bottle is filled. An optional switch is available to by-pass the automatic 28th bottle shutoff when using the composite base accessory. When the sampler is returned to sequential sample collection, the switch may be placed in the shut-off position to cease sample collection after the 28th bottle has been collected.

A COMPLETE MODEL 1680 SAMPLER CONSISTS OF:

1. THE BASIC UNIT
2. A POWER SOURCE
3. A SUCTION LINE WITH STRAINER

YOU MUST SPECIFY YOUR CHOICE OF THE ABOVE FROM 1, 2, AND 3 BELOW:

1. THE BASIC UNIT

Catalog Number	Pump	Bottles	Multiplexer
68-1680-067	Standard	Polyethylene	Yes
68-1680-068	Standard	Polyethylene	No
68-1680-069	Standard	Glass	Yes
68-1680-070	Standard	Glass	No
68-1680-071	Superspeed	Polyethylene	Yes
68-1680-072	Superspeed	Polyethylene	No
68-1680-073	Superspeed	Glass	Yes
68-1680-074	Superspeed	Glass	No

2. POWER SOURCES

Nicad Battery, without charger 60-1684-040
Lead-Acid Battery, with clamp, without charger 60-1684-042
AC power converter/battery charger. To power sampler from 117VAC, 50/60 Hz line power or to recharge battery, for use with standard speed pump samplers only 60-1684-046
Same as above, except for use with superspeed pump samplers 60-1684-048
Same as above, except for 234VAC 50/60 Hz line power, and for use with both standard and superspeed pump samplers 60-1684-093

3. SUCTION LINES

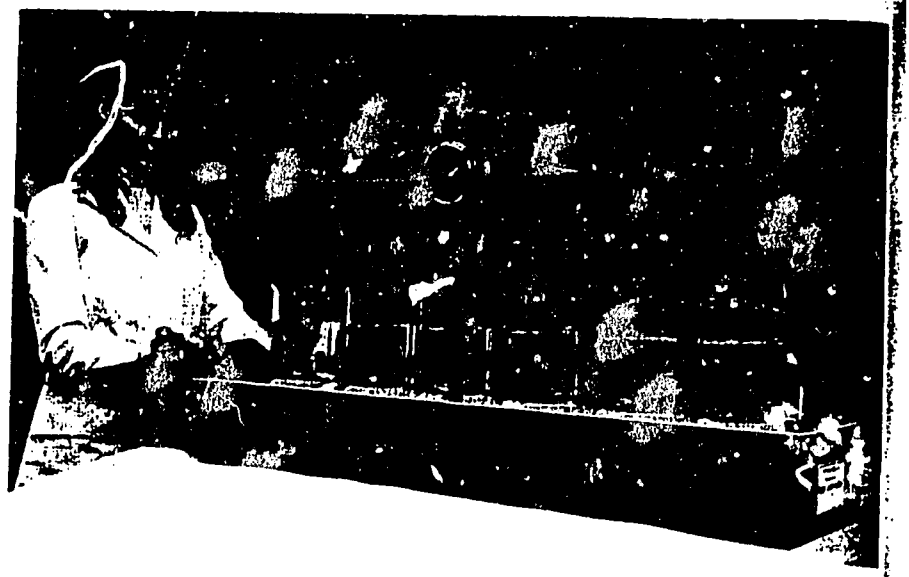
1/4" I.D. x 22' Vinyl suction line with polypropylene bubbed inlet strainer, for use with standard speed pump samplers only 60-1394-054
1/8" I.D. x 20' vinyl suction line with polypropylene bubbed inlet strainer, for use with standard and super speed pump samplers 60-1684-015

ACCESSORIES

Extra base with 28 polyethylene 500 ml bottles. Without cover 60-1394-069
Same, except 28 glass 400 ml bottles. Without cover 60-1684-100
Cover for 28 bottle base 60-1394-062
Sample bottles, high density polyethylene, 500 ml with caps with polypropylene lid liners. For Models 1680, 1392 and late Model 1391. With caps removed, will also fit Model 1390 or earlier Model 1391 (with X or W in serial number). Set of 28 68-1680-049
Same, Case of 100. Without caps 68-1680-050
Caps for Plastic bottles. Case of 100 68-1680-051
Sample bottles, glass, 400 ml, with caps with polypropylene lid liners. For use in 1390, 1391, 1392, 1680 or 1680R Samplers. Set of 28 68-1680-052
Teflon lid liners, for 400 ml glass bottle, per each 60-1683-117
Composite base only. Does not include container or locating insert. Listed separately below 60-1684-081
1 Gallon polyethylene container with lid and polypropylene lid liner. Requires locating insert below 299-0011-02
1 Gallon bottle locating insert 60-1481-020
5 Gallon polyethylene container with lid and polypropylene lid liner. No locating insert required 299-0011-01
2 ½ Gallon glass container with lid and polypropylene lid liner. Requires locating insert below 291-0400-00
2 ½ Gallon bottle locating insert 60-1481-088
Teflon lid liner for 2 ½ Gallon bottle cap 60-1481-092
Cover for composite base section only 60-1684-107
By-Pass Switch, installed 68-1680-064
Extra silicon rubber pump tube, for Models 1680 and 1392, 1" long 60-1684-016
Extra silicon rubber pump tubing, bulk, 15' long 68-1680-061

Best Available Document

c. Six Paddle Stirrer



Six-Paddle Stirrer

Saves time in water/wastewater labs

Six stainless-steel paddles stir six water samples simultaneously, at same speed.

Provide identical test conditions for all 6 samples. Ideal for determining optimum amounts of alum or ferric sulfate for flocculation tests in water and sewage.

Six paddles, 25W x 76mmL (1 x 3") driven by 1/30hp variable speed motor from 10 to 100rpm. Speed shown on tachometer dial. Paddles operate at same speed; paddle depths adjustable; any paddle can be removed without stopping the others.

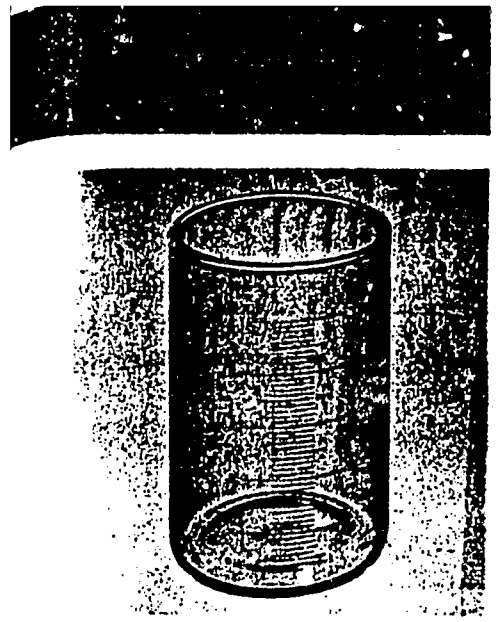
Ordering Information: Aluminum frame, 25L x 107W x 36cmH (10 x 42 x 14"). Without beakers. 120V 60Hz.

15-443-50.....575.00

Illuminator Base. For use with 15-443-50 stirrer. Consists of fluorescent lamp mounted below translucent plastic plate to provide diffused cold light through floc samples. Steel base. With fluorescent tube. 120V 60Hz.

15-443-55.....175.00

d. Direct Reading Mallory Settlometer



Direct Reading Mallory Settlometer

2-liter graduated cylinder for determination of activated sludge zone settling rate as outlined in APHA Method 213 D. Also used to determine settled volume of activated sludge according to APHA Method 213 C. Graduated in cc/liter and in hundredths of a foot. Glass, 13 dia. x 18cmH (5 x 7").

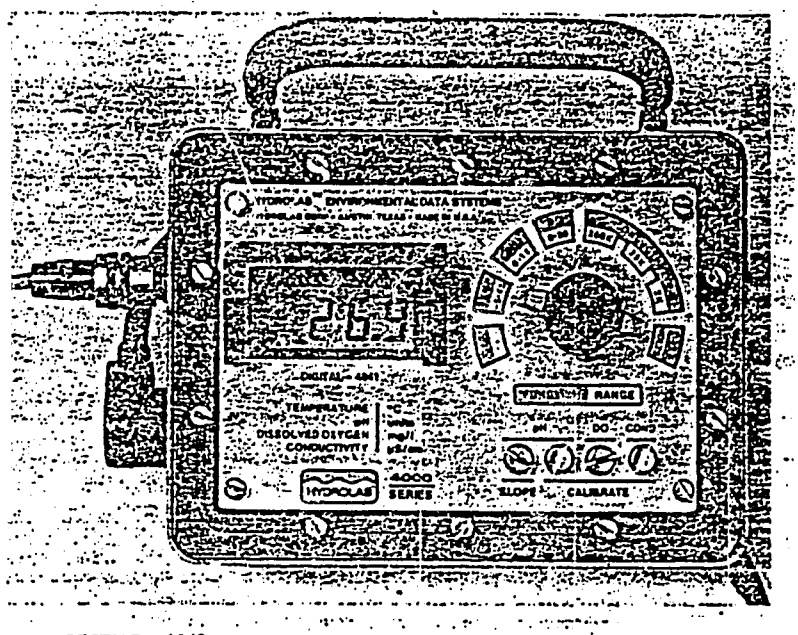
15-443-25.....79.25

e. Hydrolab Digital Water Quality Measurement System

NEW PRODUCT DATA

4000 SERIES/DIGITAL . . 4041
DIGITAL WATER QUALITY MEASUREMENT SYSTEM
TEMPERATURE, pH, D. O. CONDUCTIVITY

BULLETIN NO. 4041-8/80



MODEL: DIGITAL..4041

PARAMETERS: TEMPERATURE, pH, CONDUCTIVITY, DISSOLVED OXYGEN

APPLICATIONS:
- °in-situ measurements to 100 meters
- °Freshwater, seawater, industrial wastewater
- °Down-hole in 4-inch diameter wells
- °Laboratory analysis
- °Pumped sample through flow-cell

The DIGITAL..4041 is the more powerful of the new HYDROLAB 4000 SERIES instrument line. Powerful, but also economical as it combines (four) highly reliable parameter measurement systems in (one) compact watertight instrument case. Modern digital instrumentation techniques account for reductions in size and costs while years of field-proven sensor technology contribute to the stability and accuracy of the measurements.

Consider using the DIGITAL..4041 for every laboratory or field application which requires the routine measurement of these common water quality parameters.

Telephone (512) 255-8841
TWX 910-874-1335
HYDROLAB AUS

HYDROLAB®

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DIGITAL..4041 SPECIFICATIONS, GENERAL

A. The basic DIGITAL..4041 instrument system consists of the following:

1) Digital indicator unit (control and display device)
2) Sonde unit (submersible sensor package)
3) Sensor guard
4) Rechargeable battery pack with charger
5) Transport case
6) Accessory kit, includes:
   - Calibration cup with flexible lid
   - Storage cups (2 each)
   - Dissolved Oxygen service kit
   - pH buffer kit
   - Tool kit with supplies
7) Instruction and maintenance manual

NOTE: The basic system does not include cable which must be specified separately

B. Underwater cables and accessory items:

1) Standard cable lengths; 5, 10, 25, 50, 75, and 100 meters
2) Extension cable lengths; 5, 10, 25, 50, 75, and 100 meters
3) Motor driven circulator assembly
4) Flow-cell (pumped sample, etc.)
5) Auxiliary power cable

C. Operational limits:

1) Ambient temperature...(-20 to +50)°C
2) Relative humidity...100%
3) Maximum depth...100 meters
4) Minimum battery voltage...+10.5 volts (load)
5) Maximum battery voltage...+13.5 volts
6) Maximum added weight to sonde...20 lbs (9 kg)

D. System power requirements:

1) The DIGITAL..4041 may be powered by any suitable 12 volt battery. For operator convenience, a light-weight rechargeable battery pack is provided.
2) The dissolved oxygen system incorporates a unique cell-polarizing circuit which permits the system to be used immediately upon turning the instrument on. A 2.7 volt mercury battery in the sonde is "on" at all times and should function without replacement for at least three months.

E. Automatic Temperature Compensation:

Dissolved Oxygen, Conductivity and pH measurements are automatically temperature compensated over the range of (0-45)°C. Accuracy of the temperature compensating circuits is included in the Accuracy (overall) statement for each parameter.

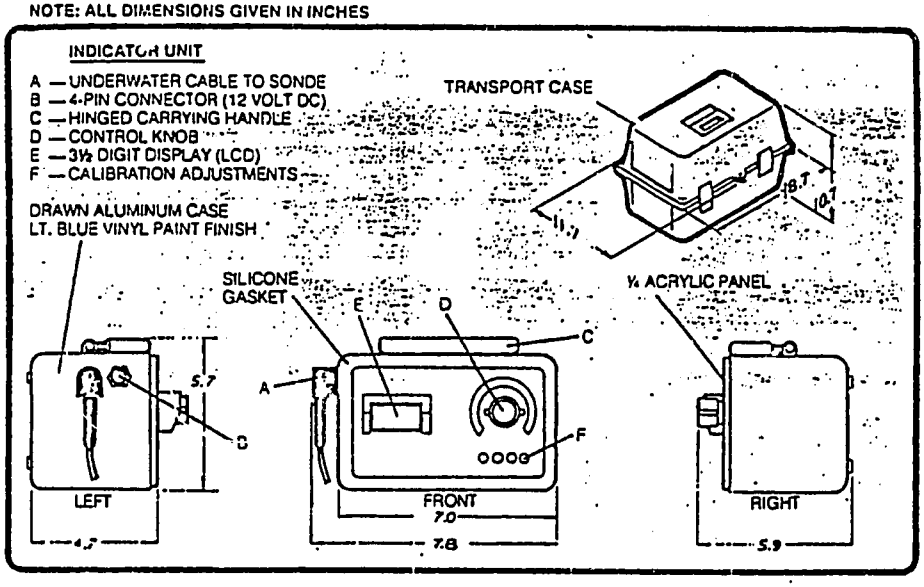
F. Automatic "Zero" corrections:

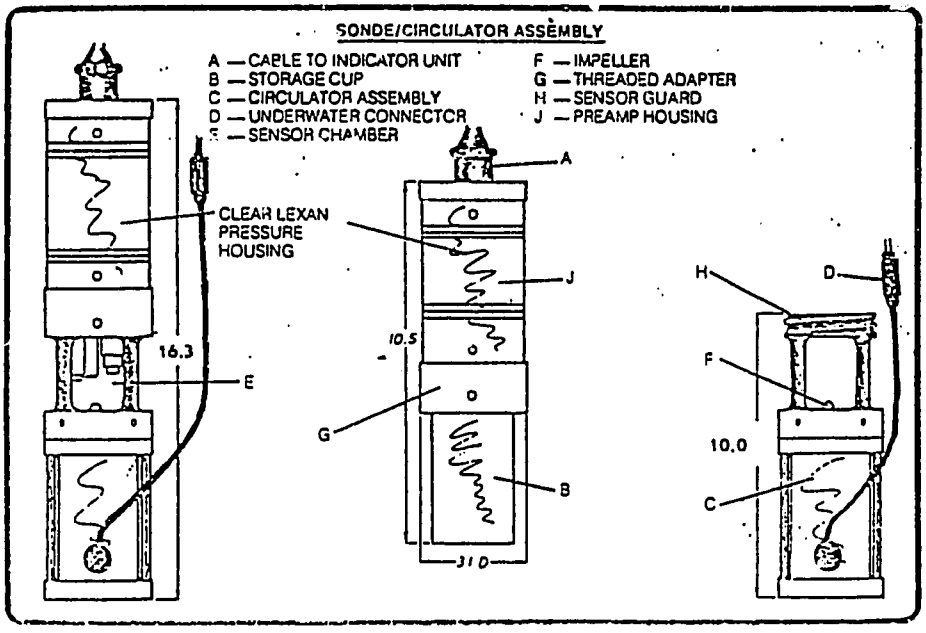
Automatic "Zero" corrections are made twice each second to provide measurement stability without the need for mechanical "zero" adjustments.

4000 SERIES

BASIC DIMENSIONS
DIGITAL . . 4041

NOTE: ALL DIMENSIONS GIVEN IN INCHES





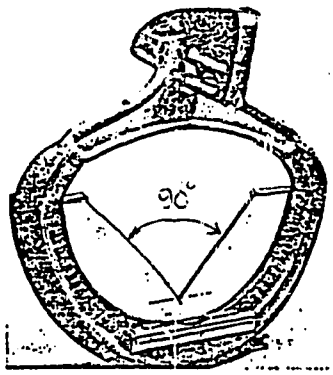
f. ND Instruments, Inc. Portable V-Notch Weir

NB INSTRUMENTS, INC.

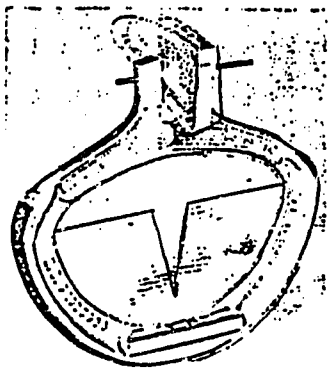
Delta Equipment Sales, Inc.
1302 Lincoln Highway
North Versailles, PA 15137
PHONE: (412) 823-9320

PORTABLE V-NOTCH WEIRS

For Measuring Flow in Manholes



90°



22½°

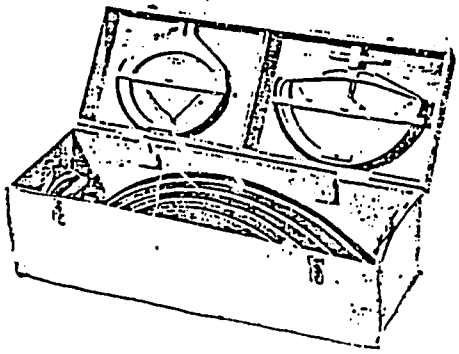
FEATURES

- Less than five minutes for installation
- Precalibrated in US gallons/24 hours
- Available for use in pipes from 6" through 60"
- Usable under very low flow conditions
- No tools required

NB's V-Notch Weir is the most economical device for testing new sewer lines or for night flow studies of existing lines.

Wherever the level of ground water is above sewer grade, use of the V-Notch Weir is the fastest and most economical method of testing tightness of lines, both for presumptive testing during construction and acceptance testing on completion of work. The adaptability of the device to very low flows also makes it useful in night flow studies in existing sewers.

Theoretically, the head to be measured in using a V-Notch Weir must be upstream of the drawdown, with impossible to realize in a manhole. Therefore, NB Instruments has calibrated its series of V-Notch Weirs* using an adjusted table based on the Cone formula: Q=2.49H2.48 where Q=discharge over weir in cubic feet per second and H=head on weir, in feet. For ease of use, the plexiglas notch is scribed with levels to show flow in terms of US gallons per 24 hours. The head of water against the plastic is simply read directly to give the daily flow. The only caution which



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must be observed is to allow sufficient time for the flow to back up and level off behind the weir, generally less than an hour.

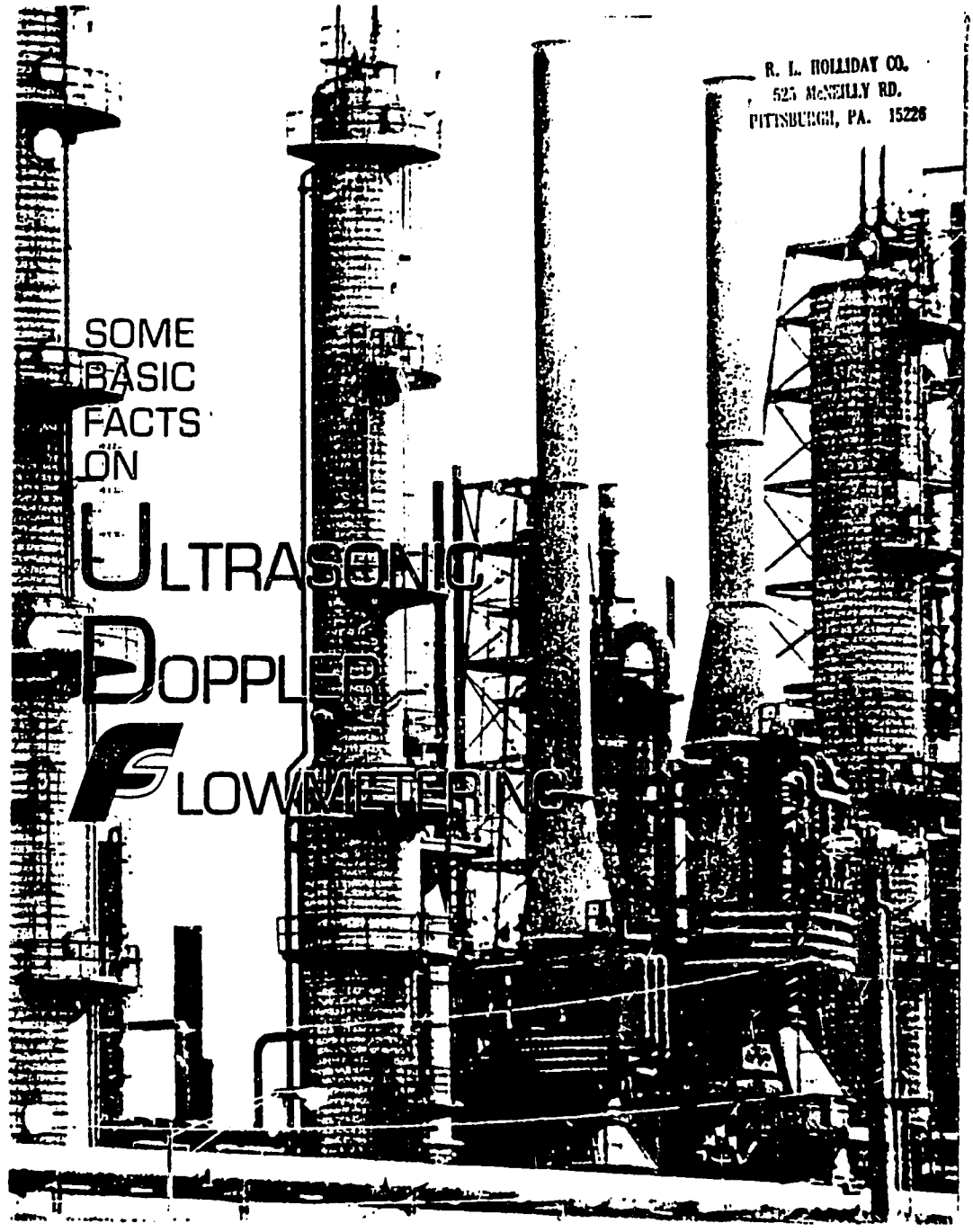
NB Instruments V-Notch Weirs are available with either 22½° or 90° notches and come in sizes suitable for 6", 8", 10", 12", and 15" pipes. A set of adaptors makes the 15" weir suitable for use in 18", 21", 24", 27", 30", 36", 42", 54", and 60" pipes. Larger adaptors are available on special order. For pipes up to 12", the weir is simply positioned, leveled by the spirit level at the bottom of the device, pressed down into place to seat the gasket, and then wedged tignt with the clamping wedge. The 15" weir is positioned in the same way, but a hand screw instead of a wedge is used to clamp the weir tight. For larger pipes, the 15" weir is set into the proper adaptor and the same procedure used. For any size pipe, installation takes less than two minutes. No tools of any sort are required.

*NB V-Notch Weirs are protected by U.S. P. 3,276,481.

V-NOTCH WEIR MAXIMUM READINGS

SIZE	90° GPD	HEAD (in.)	22½° GPD	HEAD (in.)
6	10,000	1.563	2,607	1.750
8	17,000	1.938	4,236	2.125
10	40,900	2.750	8,071	2.750
12	74,750	3.500	14,750	3.500
15	206,000	5.250	35,975	5.000

g. Portable Ultrasonic Doppler Flowmeter



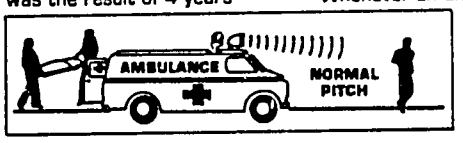
R. L. HOLLIDAY CO.
525 McNEILLY RD.
PITTSBURGH, PA. 15226

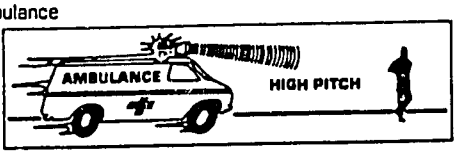
SOME BASIC FACTS ON ULTRASONIC DOPPLER FLOWMETERING

200

How it all started

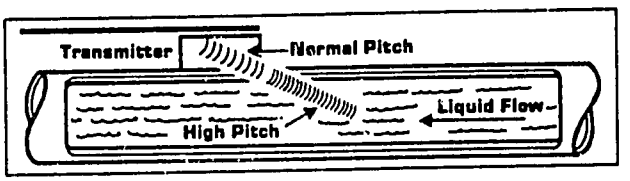
In December 1975, there was installed for the first time an instrument which was to subsequently revolutionize part of the flow measuring industry. The instrument? The first production ultrasonic doppler flowmeter. The company producing it? Flowmeter Company based in Houston, Texas USA. The instrument was the result of 4 years research and development in Europe and the United States and, since that date, doppler flowmetering has grown into a multimillion dollar industry with Flowmeter Company playing a leading role in the development and production of these units. The principle of operation is deceptively simple. We hear its effect every day of the week. Whenever an ambulance approaches you with its siren on, the sound appears higher in pitch than when the ambulance is stationary with its siren on. Here at Flowmeter Company we decided to try to utilize the effect in order to determine the rate of flow of liquids within existing pipes without broaching the integrity of pipes.

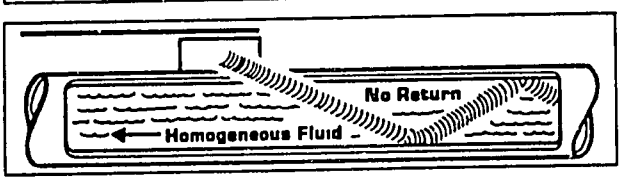


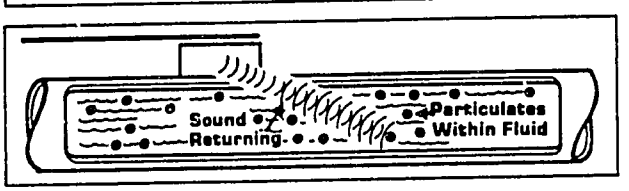


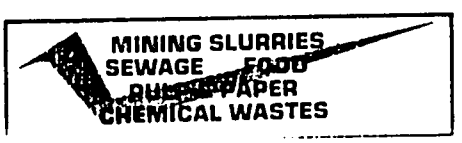
How we did it

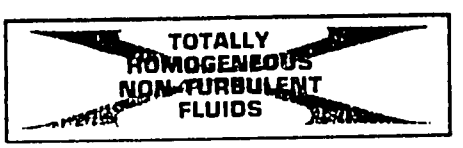
We first decided to generate an ultrasonic signal to penetrate the pipe wall and go into the fluid. Theoretically, if the fluid were moving there should have been a change of frequency within the fluid. And there was. The change in pitch, compared to the original sound was definitely proportional to the velocity of the fluid.
However, in order to detect the change, we had to compare it with the transmitted sound, back at the sound source. This meant that the sound had to bounce back to the transmitter and be detected on a receiver. In our labs, it was rapidly discovered that in order for that to occur there had to be something within the fluid to bounce the sound off. We found that if the fluid was absolutely homogeneous - with no discontinuities within it - the sound literally whistled down the pipe and never came back. There had to be entrained discontinuities, either solid or gaseous in nature scattering the beam of sound, some of which came back to the receiver.
When we had achieved this, we knew we were in business measuring the flow rate of contaminated fluids, where generally most other types of flow meters failed.
Four and a half years and over 2,000 units later, we have evolved a complete range of equipment and systems. We found along the way there are some basic do's and don'ts for successful measurements.







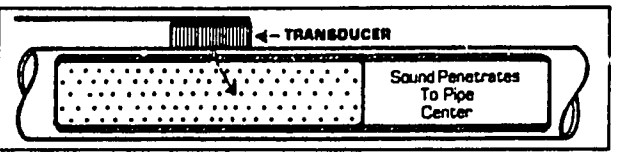




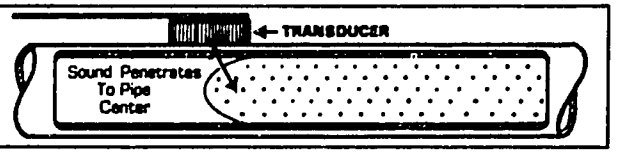
Two basic conditions exist in flowing liquids. One is turbulent flow, where the velocity of the fluid is the same at the pipe wall as it is in the center. The other is laminar flow, where the flow at the pipe wall is very slow, and gradually increases to a maximum at the center of the pipe.

In the factory, all equipment is calibrated against water with 0.25% entrained air as the reflective medium. Pipe diameter does not affect accuracy, and shown here are some typical results that may be expected in different situations.

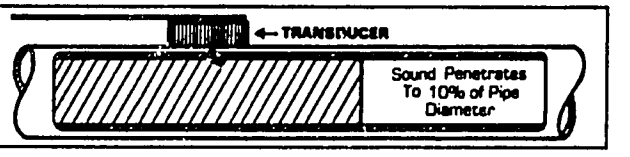
(1) Turbulent Flow
1% Solids
Expected Accuracy ± 2%
Repeatability ± 0.5%.



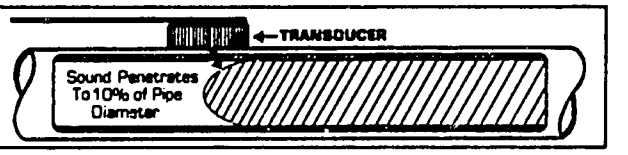
(2) Laminar Flow
1% Solids
Expected Accuracy ± 4%
Repeatability ± 0.5%.



(3) Turbulent Flow
60% Solids
Expected Accuracy ± 3.5%
Repeatability ± 0.5%.



(4) Laminar Flow
30% Solids
Accuracy. See below
Repeatability ± 0.5%



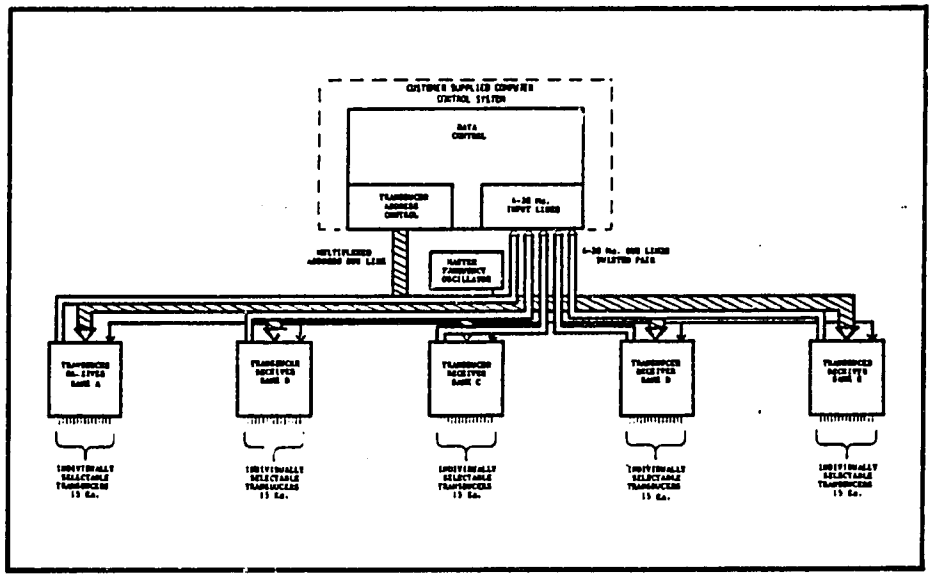
As can be seen from Diag. 4, if the fluid is so dense that the sound cannot penetrate to the center of the pipe a laminar flow condition will cause the flowmeter to read low due to a lower flow rate existing at all the points at which sound reflections occur. This problem may be resolved by recalibrating on the pipe.

Pipe Material

Most metal pipes are suitable for doppler application, but some old cast iron pipes have air bubbles which tend to scatter the beam. Plastic pipes are best for giving readings to our equipment, and a much lower volume of particulate matter may be tolerated. The transducer may be attached in one of two manners. For normal glued onto the pipe with a fast setting epoxy resin. For temporary readings such as with one of our portable flowmeters, the transducer should be taped to the pipe with silicone grease or similar material taking the place of the epoxy resin. Obviously, the above does not cover even a small percentage of the gained over the last few years. We have found that nearly every flow problem has its unique points which have to be considered, so if you have a problem and you're not sure if ultrasonics can do the job, telephone us, WE WILL LEND YOU A PORTABLE FREE TO FIND OUT IF IT IS SUITABLE OR NOT

As has been mentioned elsewhere very often the flow problems are unique and require custom building to customer specifications.

At Flowmeter Co. our design staff is constantly at work on special applications ranging from simple modifications on single flowmeters to systems such as that shown below where 75 pipes in 5 banks of 15 had to be monitored sequentially 5 at a time.



If you have a problem flow why not contact your nearest Flowmeter Co. distributor or telephone the factory directly. We will be pleased to discuss at length your particular flow problems. We may be able to solve the problem in a very economic and efficient way, but if we think that doppler is not suitable for your particular application we will tell you so. Some manufacturers of doppler flowmeters are making exaggerated claims for their equipment. For example there are many flow streams where a magnetic flowmeter is vastly superior to a doppler unit, though at least one manufacturer of doppler equipment would have you think otherwise. Every type of flowmeter has its limitations and doppler is no exception. However, in this brochure we have tried to explain where doppler flowmeters function best so that you, the end user, will be able to decide whether or not to "go doppler."

FLOWMETER COMPANY

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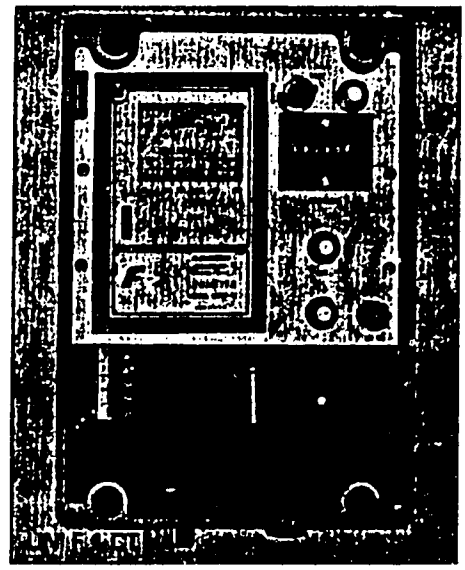

UNIMETER F SERIES PERMANENT FLOWMETERS

The 'F' series of flowmeters are designed as general purpose doppler flowmeters for dirty streams. They have found wide acceptance in a variety of applications ranging from cooling water and mining ore slurries to sewage lines, chemical wastes and the like. The basic unit is the UNI F1, an indicating flow transmitter. Many different options are available, both standard and custom, in order to tailor the instrumentation precisely for specific needs and applications.

BASIC UNI F1

FLOW RANGE	Generally specified by customer in either velocity or volumetric rate units but standard 0-10 fps + 100% - 50% by means of a ten turn calibrated span control.
INDICATION	3" dia 270° analog meter scaled 0-100%.
ACCURACY	Typically better than 4%.
REPEATABILITY	Better than 1%.
OUTPUT	4-20 mA, 10-50 mA, 0-20 mA, 0-50 mA. (Specify which).
POWER	115/220 VAC. 50/60 HZ.
TRANSDUCER	Length 20' Temperature 175°F, 80°C.
CASE	NEMA 4 fiberglass 12" x 8.5" x 7" (305 x 215 x 175 mm). Weight 9 lbs (4.1 Kg.)
OPTIONS.	Specify by suffix to be added to UNI F1.

SUFFIX

C_____**CHART RECORDER.** 2¼" inkless. 60' roll. Speeds from 0.125 iph.

T_____**TOTALIZER** Six digit resettable electro-mechanical programmable.

S_____**SET POINTS.** Hi-Lo 10%-100% of rate. C form contacts out.

B_____**BATCHER.** 3 digit programmable 001-999. C form contacts out.

H_____High temperature transducer up to 305°F, 150°C.

Transducers of different lengths available up to 500'. (Consult factory before ordering).

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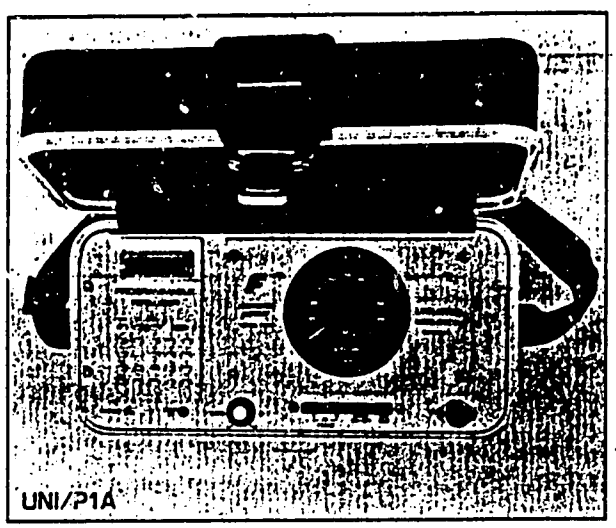

UNIMETER P SERIES PORTABLE FLOWMETERS

These flowmeters feature high portability where spot checks of flow, periodic calibrations, or any temporary flow measurements are required. They are also useful in determining where suitable applications exist for dedicated flowmeters of the doppler type.

There are two basic models.

- P1 Series in rigid vinyl shoulder strap case.
- P2 Series in NEMA 4 fiberglass case. The P2 Series, besides having all the features of the P1 series, also has a 4-20 mA output.

	Uni P1 A/ P2 A	Uni P1-C /P2-C
FLOW RATES	0-5 fps, 0-10 fps, 0-20 fps, or 0-1.5 m/s, 0-3 m/s, 0-6 m/s.	0-5 fps, 0-10 fps, 0-20 fps, or 0-1.5 m/s, 0-3 m/s, 0-6 m/s.
INDICATION	3" Dia 0-270° Scale analog meter Accuracy typically better than 4% Repeatability better than 1%	2¼" wide inkless chart, feed rate 30 iph. Roll length 60'. Accuracy typically better than 4%. Repeatability better than 1%.
TOTALIZATION	Eight digit LCD rapid programming, solid state totalizer/calculator.	Eight digit LCD rapid programming, solid state totalizer/calculator.
TRANSDUCER CABLE LENGTH	20 feet	20 feet
POWER SOURCE	20 hour life rechargeable cells or 115/220 VAC 50/60 HZ via charger	20 hour life rechargeable cells or 115/220 VAC 50/60 HZ via charger
DIMENSIONS	P1A 12" (305mm) x 9" (230mm) x 6" (152mm) P2A 12" (305mm) x8.5" (215mm) x 7" (176mm)	Same as P1A/P2A
WEIGHT	P1A 6.5 lbs (2.95 Kg) P2A 9.5 lbs. (4.3 Kg)	P1C 9.5 lbs (4.3 Kg) P2C 12.5 lbs (5.7 Kg)

TRANSDUCER

The standard transducer supplied with the equipment is 20' long and will withstand pipe temperatures of up to 175°F (80°C)

Longer lengths available up to 500' (Consult factory before ordering) High temperature transducers available for pipe temperatures up to 305°F (150°C)

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