The Cost of Clean Water

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

VOLUME III

INDUSTRIAL WASTE PROFILE NO. 1
BLAST FURNACES AND STEEL MILLS

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THE COST OF CLEAN WATER

Volume III

Industrial Waste Profiles
No. 1 - Blast Furnace and Steel Mills

U. S. Department of the Interior
Federal Water Pollution Control Administration

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PREFACE

The Industrial Waste Profiles are part of the National Requirements and Cost Estimate Study required by the Federal Water Pollution Control Act as amended. The Act requires a comprehensive analysis of the requirement and costs of treating municipal and industrial wastes and other effluents to attain prescribed water quality standards.

The Industrial Waste Profiles were established to describe the source and quantity of pollutants produced by each of the ten industries studied. The profiles were designed to provide industry and government with information on the costs and alternatives involved in dealing effectively with the industrial water pollution problem. They include descriptions of the costs and effectiveness of alternative methods of reducing liquid wastes by changing processing methods, by intensifying use of various treatment methods, and by increasing utilization of wastes in by-products or water reuse in processing. They also describe past and projected changes in processing and treatment methods.

The information provided by the profiles cannot possibly reflect the cost or wasteload situation for a given plant. However, it is hoped that the profiles, by providing a generalized framework for analyzing individual plant situations, will stimulate industry's efforts to find more efficient ways to reduce wastes than are generally practiced today.

James M. Quigley

Commissioner
Federal Water Pollution Control Administration

INDUSTRIAL WASTE PROFILE

BLAST FURNACE AND STEEL MILLS

SIC 3312

Prepared for F.W.P.C.A.

FWPCA Contract Number 14-12-98

September 28, 1967

Federal Water Pollution Control Administration
September 1967

SCOPE OF MATERIAL COVERED

This profile study was undertaken to provide the Federal Water Pollution Control Administration with comprehensive information on the waterborne wastes of the blast furnace and steel mill industry - SIC 3312. This industry includes establishments primarily engaged in manufacturing hot metal, pig iron, silvery pig iron, and ferroalloys from iron ore and iron and steel scrap; converting pig iron, scrap iron, and scrap steel into steel; and in hot-rolling steel into basic shapes such as plates, sheets, strips, rods, bars, and tubing. Merchant blast furnaces and by-product or beehive coke ovens are also included in this industry.

Most of the iron and steel industry in the United States is centered in the integrated facilities of large corporate enterprises; the eight largest producers are among the 100 largest industrial corporations in this country. The comparatively small integrated producer in this industry represents a very large industrial complex. Even the smallest producer in the industry may not be considered a very small industrial operation.

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SUMMARY OF REPORT

Pig iron is produced in the blast furnace, utilizing iron ore, coke, and limestone as the raw materials. Steel is produced in a variety of processes such as the open-hearth furnace, the basic oxygen furnace, the electric furnace, and the Bessemer converter; the modern steelmaking processes utilize a large percentage of steel scrap in addition to pig iron and various alloying elements.

Molten steel is cast into ingots and delivered to the primary rolling mills, where semifinished shapes such as blooms, slabs, and billets are formed. Slabs and billets may be formed directly by the newer continuous casting process. Semifinished shapes are further reduced by rolling on secondary mills into such shapes as plates, strip, bars, structural shapes, rails, and tubes. Various cleaning operations are required during the rolling steps to remove oxide films, dirt, and oil. The cleaning operations include water washing, shot blasting, pickling, and the use of detergents and solvents.

A given plant may ship iron or steel at any stage of production as its final product. Many plants, however, further finish the secondary mill products by cold reduction, galvanizing, tinplating, coating, tempering, polishing, etc. Large steel plants operate coke ovens, producing metallurgical coke from coal, since this ironmaking raw material is used in such great quantities.

Significant waterborne wastes result from almost all steel mill manufacturing operations. These wastes are principally suspended solids, oils, heated water, waste acids, plating solutions, and dissolved organic chemicals. Steel industry wastewaters are unique among industrial wastes in that the volumes of the effluent streams are so great.

The principal waste from the blast furnace operation is water used in washing the exit gases from the furnace free of suspended solids; similar wastes result from sinter plant operations, which are usually part of the blast furnace department. To a large extent these wastes result from air pollution abatement measures, but blast furnace gas must be cleaned to permit its use as a fuel. The principal pollutant is the solid material suspended in the wastewater. Waterborne wastes from steelmaking operations result from washing exit gases with water to prevent air pollution. These wastewaters are similar to blast furnace gaswasher water and are produced mainly by the newer steelmaking furnaces.

Continuous casting machines and hot-rolling mills produce wastewaters which contain suspended solid materials, oils, and dirt. The various cleaning operations produce wastewaters containing saponified oils, dirt, alkali, and solvent residues. The principal waste from cleaning operations is spent pickle liquor, which consists of solutions of

various acids and the iron salts of these acids. Spent pickling solutions represent by far the most difficult wastewater problem of the industry.

Effluents from steel finishing operations contain emulsified oils and suspended solids, principally resulting from cold-rolling and cold reduction mills. The various plating operations, particularly electrolytic tinplating and galvanizing and chromium plating, produce wastewaters containing soluble metals; such sources of pollution are usually rinsewaters.

Coke plant wastes originate as ammonia still wastes, coke quenching effluents, light oil decant waters, and acid washing effluents, and contain phenols, cyanides, ammonia, and chorides. These materials may appear alternatively in blast furnace gaswasher water when the coke plant effluent is used to quench coke.

Gross water intake by the industry in 1964 was 3,815 billion gallons; gross water use, including recirculation and re-use was 5,510 billion gallons. Overall water re-use was thus 42.1 per cent. Cooling water re-use is estimated to have been 52.2 per cent and process water re-use 18.1 per cent. Water uses by the industry are summarized in the following table, for the year 1964; uses are in billions of gallons.

Manufacturing Process	Process Water	Cooling Water
Blast furnaces	276	586
Open-hearth furnaces	1	491
Basic oxygen furnaces	8	37
Electric furnaces	1	63
Hot-rolling mills and related	468	468
Cold mills and related	264	-
Coke plants	6	632
Sanitary, boilers, etc.	-	254
Blowers, condensers, etc.	-	1955
	1024	4486

The general trend in the steel industry is toward the use of subprocesses which will produce products of lighter unit weight at increasingly higher speeds with minimum manual operations. Production units generally tend toward the largest sizes in order to realize the economies of scale. The rate of adoption of the newer processing technologies can be seen by the following data on past and projected uses of selected subprocesses, in terms of percentages of plants using each.

Subprocess	1950	1963	1967	1972	1977
Bessemer converter	10.3	6.0	4.3	2.0	0
Open-hearth furnaces	49.1	41.7	39.6	35.0	30.0
Basic oxygen furnaces (1)	0	7.3	13.7	25.0	35.0
Ingot Molding	47.9	49.7	51.1	50.0	40.0
Continuous casting (1)	0	1.3	7.9	15.0	25.0

(1) Newer Technology

Particularly difficult waste problems arise from certain steel industry subprocesses, especially some of the newer production methods which are geared to high-speed, high-volume outputs. The gaswasher water from ferromanganese furnaces contain particles of sub-micron sizes which are extremely difficult to separate by sedimentation. Such furnaces also produce effluents which contain greater concentrations of cyanides than those from ironmaking furnaces. The wastewaters from basic oxygen furnaces contain very fine suspended particles which are difficult to treat; the wastewaters from oxygen-lanced open-hearth furnaces are similar.

The very fine particles in the wastewaters from the newer hot-strip mills are not readily separated in ordinary sedimentation equipment and impart black or red colors to effluent streams, even in low concentrations. Effluents from cold mills contain soluble oils which require extensive treatment for removal. Such emulsions are particularly stable when detergents are used in the rolling operation.

Coke plant effluents present particularly difficult waste control problems. Phenols and cresols can be reduced by relatively simple processes, but are further reduced to the point acceptable for discharge in most instances with great difficulty.

A general characteristic of steel industry effluents that makes for difficult waste control problems is their large volumes. Most industrial waste discharges are not of the magnitude found in the steel industry. A waste stream flowing at 10,000 to 25,000 gallons per minute presents a difficult treatment problem.

There is no generally accepted standard of plant size in the industry. Based upon analysis of available data, the following categories appear to be reasonable; the data indicate the percentages of plants in each size grouping in 1967.

Plant Size	Per Cent of Plants	Ingot Tons Produced Annually
Small	53.9	Less than 1,000,000
Medium	15.2	1,000,000 to 2,000,000
Large	30.9	More than 2,000,000

Levels of technology in the industry may be described according to the relative prevalence of certain subprocesses in a particular plant. Not all subprocesses can be easily categorized; subprocesses that are considered descriptive of technology levels are tabulated in the following table.

Subprocess	Level of Technology
Blooming Mill	Old and Typical
Sinter Plant	Typical and Advanced
Basic Oxygen Furnace	Advanced
Continuous Casting	Advanced
Hot-Dip Tinplating	Old
Cold Reduction	Typical and Advanced
Vacuum Degassing	Advanced
Beehive Coke Ovens	Old

The percentages of plants in the industry according to technology level and plant size are given below, based upon the considerations and assumptions mentioned.

	Level of Technology		
Plant Size	Old	Typical	Advanced
Small	32.0	54.7	13.3
Medium	30.0	55.7	14.3
Large	27.9	34.9	37.2
All	30.4	48.7	20.9

Waste loads, in pounds produced per ingot ton per day, by plants operating at the various levels of technology are summarized in the following table.

	Level of Technology		
Waste	Old	Typical	Advanced
Suspended Solids	103	125	184
Phenols	0.069	0.064	0.064
Cyanides	0.029	0.028	0.031
Fluorides	0.033	0.031	0.031
Ammonia	0.082	0.078	0.078
Lube Oils	3.08	2.72	2.37
Free Acids	3.03	3.54	3.40
Combined Acids	11.3	13.2	12.6
Emulsions	0.332	0.414	1.17
Soluble Metals	-	0.079	0.082

Waste Water volumes produced, per ingot ton per day, are summarized below for plants at the various levels of technology.

Level of Technology	Wastewater Volume, gallons
Old	9,860
Typical	10,000
Advanced	13,750

Alternative subprocesses in ironmaking are limited to the variations in blast furnaces and their operations and to the use of sintering. Processes such as direct reduction which replace the blast furnace are not likely to be soon adopted in this country to any significant extent. The alternative subprocesses in steelmaking are the oxygen-lanced open-hearth furnace and the basic oxygen furance. The electric furnace tends to fill specialized steelmaking requirements and is not usually alternative to the other steelmaking methods.

Continuous casting is an aternative to the sequential operations of ingot molding, soaking, rolling blooms, and rolling slabs or billets. Hot-rolling operations are alternative to one another principally in the size and speed of the mill. Methods of conditioning semifinished steel may be considered as alternatives and include chipping and grinding, hand scarfing, and hot-scarfing machines. Oxide films may be removed from steel by pickling in sulfuric or hydrochloric acids, or by the use of shot blasting; these may be regarded as alternative subprocesses.

Tinplating by the hot-dip and electrolytic processes are alternative to one another and to chromium plating. The hot-dip and electrolytic galvanizing processes are alternative subprocesses. Most other steel mill operations do not have clearly defined alternative subprocesses.

In general, the subprocesses representative of the newer technologies in steel mill operations produce greater waterborne waste loads than do the older manufacturing methods. This characteristic of the newer technologies is due to the fact that lighter products are becoming more predominate in the industry and to the generally increasing production rates. Wastes are generated in proportion to the surface area of steel exposed during rolling and finishing operations and in proportion to the relative gas-liquid interfacial areas in ironmaking and steelmaking operations; the newer technologies tend to maximize these areas and to thus generate greater unit waste loads. The newer installations do, however, generally incorporate waste treatment facilities and actual plant discharges are not necessarily greater in newer plants. The exceptions to this generality are found in the cases of continuous casting and of shot-blast cleaning; these newer subprocesses are alternatives to ingot molding, etc. and pickling, respectively, reduce waste loads.

Blast furnaces are becoming larger and sinter plants are increasingly utilized due to the need of higher production rates and the decreasing quality of available ores. Sintering reduces flue dust losses from blast furnaces, but increases the total plant waste loads. Basic oxygen furnaces are being built to replace conventional open-hearth furnaces; open-hearth furnaces will, however, continue to operate with oxygen-lancing. Electric furnaces will exhibit steady, slow growth, independently of increasing basic oxygen furnace capacity.

Continuous casting is yet in its infancy in this country, but is steadily being put into commercial operation. The very large investments in ingot molding, soaking pits, and primary rolling mills will not permit the wholesale adoption of this technique in the near future; the technique is not completely substitutable for the other operations in any case at present.

Hot-strip mills are becoming larger and faster and roll thinner gauges due to higher production requirements and to the market demand for thinner strip. Hot-scarfing is being increasingly used due to the market demand for higher quality products. Hydrochloric acid is substituted for sulfuric acid to obtain faster pickling and to produce a better surface on the product. Shot blasting is limited as a substitute technique for pickling due to the investment in pickling facilities and due to the limitations of available machines.

Electrolytic tinplating and glavanizing replace hot-dip processes due to the higher production rates possible with the newer processes and to the reduced plating metal used per unit of plated surface. At least one producer is experimenting with chromium plating as a substitute for tinplating on a commercial basis; the potential market is in the container industry.

The principal wastes of the industry may be described in broad terms as suspended solids, lubricating oils, acids, soluble metals, emulsions, and coke plant chemicals. These substances appear in effluents in various combinations, depending upon the particular manufacturing operations in which the wastes are generated. For example, suspended solids appear with coke plant chemicals in blast furnace gaswasher water, alone in effluents from basic oxygen furnace gas scrubbers, with lubricating oils in hot-mill effluents, and with emulsions in cold mill effluents. The methods of treatment and the efficiencies of treatment methods vary depending upon the sources of wastes and the combinations in which they occur.

Suspended solids from blast furnace gaswasher water and sinter plant effluents may be removed by plain sedimentation and by coagulation and sedimentation; recirculation of the wastewater may be used with either method. Similar treatment may be used to remove suspended solids from hot-rolling mills, but provision must be made for removal of flotant oil by skimming. Suspended solids may be removed from cold mill effluents by various sedimentation methods, but the emulsions present must first be broken; magnetic separators can be used to remove these solids without regard to the emulsion.

Lubricating oils are generally removed by allowing adequate time for flotation and then skimming the oil from the water surface. Chemical treatment, which results in absorption of the oil by floc particles, is required to remove such oils substantially completely. Emulsions must be broken in order to allow the oil to separate, float, and be skimmed from the water surface, especially if detergents are present which act to stabilize emulsions.

Waste acids may be disposed of in deep wells, reduced in effluents by using regeneration techniques, or treated by neutralization with alkaline agents. None of these techniques are applied to the treatment of acid rinsewaters which, although dilute, contain 15 to 25 per cent of the acid used in pickling. Deep wells are limited both by local and state regulations for waste disposal in some cases and by geological considerations in others; the technique is increasingly used, however, and is often the least costly disposal method for waste acids. Regeneration processes for waste acids are technically feasible, but have not been widely used because of the expense involved; the regeneration of hydrochloric acid is technically easier and less expensive than of other acids. Neutralization requires less capital investment than regeneration processes; there are not credits obtainable for the resulting sludge and the expense of lagooning the sludge is high. The land used for lagooning sludge is usually unfit for subsequent use.

Soluble metals in plating rinsewaters may be disposed of by deep well injection and by ion exchange methods; combination of such effluents with acid wastes and subsequent neutralization and lagooning is another treatment method. The chemicals present in coke plant effluents are often reduced by quenching hot coke with these wastewaters; some of these materials appear then, however, in the blast furnace gaswasher water. Deep well disposal can be used here and biological treatment processes are effective in reducing these materials in effluents.

Treatment facilities must be properly operated if effective waste reduction is to be realized. Many plants operate waste treatment facilities efficiently and exercise close control over the treatment plant operators. Others, however, often turn such duties over to untrained labor and accomplish little waste reduction, even after the installation of otherwise adequate facilities.

The extent to which recirculation of process water is practiced and the degree to which air pollution abatement is undertaken by wet-scrubbing methods are the factors of greatest importance in determining waste loads from given production processes. Waterborne wastes can be all but eliminated by recirculation of process water; steelmaking processes would generate little or no waterborne wastes if exit gases were not scrubbed with water.

Spent pickling solutions and coke plant wastes can be discharged tomunicipal sewers and treated with municipal wastes. This is not practiced widely in the industry. Acids can attack sewer materials and inhibit the biological processes in sewage treatment plants; sulfates can cause corrosion in concrete sewers of certain types. Coke plant wastes can inhibit sewage treatment processes due to the toxicity of phenols and cyanides. Pickle liquor must be partially neutralized before discharge to municipal sewers and the flow rate must be regulated in relation to the relative volumes of sewage to which it is added. Coke plant wastes must be added by controlled discharge so as not to upset the treatment plant processes.

By-product recovery and utilization is inherent in certain steel industry waste treatment operations. By-product recovery and utilization in the sense that some marketable commodity is manufactured from a waste stream component, is not found in the industry and it is not likely to be developed. The reason lies in the fact that the steel industry is a heavy industry, utilizing raw materials and producing products that are cheap on a weight basis; expensive processing cannot be justified to recover such materials.

The suspended material from blast furnace gaswasher water and recovered mill scale are sintered and returned to the blast furnace or steel-making furnace for reprocessing. Oils recovered from cold mill rolling solutions are processed for re-use in the mill operation or for sale. Acid regenerated from spent pickle liquor is returned to the pickling tanks.

Some other by-products are recovered in the course of gas-scrubbing cleaning operations which reduce potential waste loads well ahead of the point of discharge of water effluents. Ammonium sulfate is produced in removing ammonia from coke oven gas with sulfuric acid; phenol is recovered from coke oven gas by vapor recirculation or solvent extraction. Copperas is produced from pickle liquor in a few plants and one or two plants are able to dispose of pickle liquor to chemical or pigment manufacturers.

In the eight years from 1955 to 1963, steel capacity increased from 125 to 155 million tons per year: During this period the industry invested about 1.42 billion dollars per year in plant and equipment in terms of 1965 prices. The replacement value of plant and equipment in the industry is estimated to be about 60 billion dollars in terms of current prices, or an average of $387 per annual ingot ton of capacity. The value of older equipment producing heavier unit products is about 2/3 of this average value, while that of newer equipment producing lighter unit products is about 1/3 greater.

The estimated replacement value of waste treatment facilities installed in 1966 is estimated to have been 865 million dollars, or about 1.44

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per cent of the total investment in plant and equipment. Waste treatment facilities in the newest production facilities under construction are reported to cost six per cent of the total plant cost. Waste treatment facilities in an integrated mill which utilizes a high degree of process water recirculation with minimum treatment are reported to average 4.5 per cent of the total investment in production facilities.

Operating costs for waste treatment processes and for production processes may be considered in terms of direct and indirect costs. Direct costs include labor, supervision, maintenance and supplies; indirect costs include amortization, general overhead, taxes and insurance. Based upon the average plant size, the estimated percentages of plants utilizing particular waste treatment processes, steelmaking production of 135 million ingot tons per year, and the wastewater volumes outlined herein, the annual expenditures by the industry in 1966 for waste treatment are as follows:

Cost Component	Amounts in 1966	Per Ingot Ton
Direct	$90,104,240	$0.667
Indirect	53,815,670	0.398
Credits	53,601,860	0.397

Operating labor costs in the steel industry are approximately 54 per cent of the value added by manufacture, which was about $78.50 per ingot ton in 1966. Materials, supplies, freight and other services amounted to about $60.50 per ingot ton, indicating direct operating and maintenance expenditures of $102.90 per ingot ton in 1966. Direct expenditures for waste treatment in the industry are thus estimated to be approximately 0.65 per cent of the direct expenditures for production.

Average waste treatment costs cannot be applied to specific plants without careful consideration of all of the factors involved. The costs of waste collection and conveyance to a treatment site may be minimal in one plant and exceed all other costs in another. The age of the production plant and particularly the available space for treatment facilities are important variables in waste treatment costs. In general, waste treatment facilities in older, crowded mills cost 135 per cent of the average, while facilities in new mills may cost 70 per cent of the average.

The average economic life of production facilities in the industry is estimated to be 26 years. The actual life of any particular production facility is very difficult to define, since some pieces of equipment are actually rebuilt many times before being finally discarded, usually on account of obsolescence. The economic life of waste treatment facilities is about 15 years on the average; the actual lives of particular waste treatment facilities are extremely variable. An acid neutralization plant may last 10 years, while a scale pit in a rolling mill could last 50 years.

The estimates of waste loads, wastewater volumes, treatment and production methods, and costs given in this report are considered to be descriptive of the industry. It must be remembered that this industry is extremely hetrogeneous. Every plant in the industry has some uniqueness and these differences can be of critical importance in assessing water and waste problems.

I. Processes and Wastes

Generalizations about steelmaking operations are difficult, and exceptions can be found in any mill. Steel mills in operation today range from new, modern mills built within the last decade to older marginal facilities built early in this century. Manufacturing operations in the industry may be grouped as ironmaking, steelmaking, steel casting, steel rolling, cleaning, finishing, and coke manufacturing. A single mill is not likely to incorporate all of the many combinations and variations of these operations that are possible. Most mills specialize in the production of broad categories of steel products; in a large mill, however, the product list is very long.

A. Fundamental Manufacturing Processes

Pig iron as produced in the blast furnace is too soft for most industrial uses; it must be further refined to produce steel which is the form in which most iron is utilized. Steel may be defined as an alloy of iron and carbon, with or without special alloying elements. Steel is produced from pig iron by adjusting the carbon content of the alloy to less than 2%. The principal steelmaking processes include the open-hearth furnace, the basic oxygen furnace, the electric furnace, and the Bessemer converter; modern steel production processes utilize a large percentage of steel scrap in addition to pig iron.

Molten steel as produced by the various processes must be converted into solid forms for production of usable products; this is the process referred to as steel casting. Most steel today is cast into a tapered mold and allowed to solidify, producing a shape known as an ingot. The ingot is the form in which steel is delivered to the rolling mill. Continuous casting of steel into smaller, more readily usable shapes is a recent development which eliminates ingot molding. Cast steel is formed into a wide variety of finished and semifinished shapes by squeezing the heated metal between heavy steel rolls. Primary mills form ingot into slabs, blooms, and billets. There are no precise definitions of these terms; distinctions are made according to general appearance, influenced by overall size and by intended use. A slab is an oblong form 2 to 9 inches thick and 24 to 60 inches wide. A bloom is a square shape from 6 to 12 inches wide. A billet is a square shape from 2 to 5 inches wide. These products of the primary mills are further reduced by hot-rolling to plates, strips, bars, structural shapes, rails, and tubes. During the rolling process, the steel acquires a coating of oxide which must be removed before further processing or sale. The oxide coating is removed by pickling in an acid bath or by mechanical means such as shot blasting. Many steel products,

particularly strip steel, is cleaned by using alkaline and detergent solutions; such cleaning operations are used throughout many stages of production, particularly in the production of tinplate to remove accumulated oils and dirt. Finishing operations consist of cold reduction, galvanizing, tinplating, chromium plating, coating with various synthetic resins, coating with other metals or inorganic materials, and various tempering and polishing operations. The steel forms produced from these operations constitute the saleable products of the industry. Coke plants are operated by the steel industry because of the large quantities of coke used in the ironmaking process. Bituminous coal is baked in ovens in the absence of air; the volatile material is driven off, leaving the hardened residue known as coke. The volatile materials are recovered and converted into by-products in coke ovens known as by-product ovens. The beehive coke oven, which is rarely used in the United States today, produces coke without the recovery of by-products.

B. Water Wastes

Significant waterborne wastes result from almost all steel mill manufacturing processes. These wastes are principally suspended solids, oils, heated water, waste acids, plating solutions, and dissolved organic chemicals. Steel industry wastewaters are unique among industrial wastes in that the volumes of the effluent streams are so great.

1. Cooling Water

Water that is used for indirect cooling is polluted only to the extent that its temperature is raised. The temperature rise probably averages about 10°F. The actual temperature of the effluent depends upon the temperature of the intake water, which is generally a function of the season of the year when a surface water source is used. Ground water sources are usually at non-uniform temperatures year-round. Certain highly industrialized rivers are quite warm, even during the coldest winter months and cooling water discharged is likewise above average in temperature.

2. Blast Furnace Wastewaters

The water used in washing blast furnace flue gas free of dust particles contains from 1,000 to 10,000 mg/liter of suspended solids, which approximate the composition of the furnace burden. Following a slip in the furnace, the concentration of suspended solids may be as much as 30,000 mg/liter. Blast furnace gaswasher water may amount to 600 to 5,000 gallons per minute per furnace, depending upon the type of washer used. The suspended solids from an iron-producing

furnace are generally 50 percent finer than 10 microns in diameter and have a specific gravity of about 3.5 on the average; the effluent is red in color. A furnace producing ferromanganese discharges particles which are extremely fine and are lighter in color than those from an iron-producing furnace.

Blast furnace gaswasher water contains significant concentrations of cyanides, phenol, and ammonia in addition to suspended solids. Gaswasher waters from ferromanganese furnaces have much higher concentrations of cyanides than do washwaters from iron furnaces.

These wastewaters result from a gas-cleaning operation and thus prevent to a considerable extent air pollution which would otherwise result. The primary reason for cleaning the gas, however, is to allow its use as a fuel.

Quenching blast furnace slag produces small quantities of water containing slag particles. The effluent from a slag pit may range from 100 to 200 gallons per minute and is of a clear appearance.

The dust produced from the sintering plant operation is often recovered through the use of wet washers operating on the exhausts of hoods and building ventilators. Such wastewashers are very similar to blast furnace gaswasher water insofar as suspended solids are concerned; cyanides, phenol, and ammonia are not found in such effluents. A typical wet washer will produce an effluent of 1000 gallons per minute. This wastewater is produced as the result of air pollution abatement measures.

3. Steelmaking Wastewaters

Waterborne wastes from steelmaking operations result from washing the exit gases with water as an air pollution abatement measure. The suspensions of solids which result are similar to blast furnace gaswasher water, but the particles are generally much finer. These wastes may be generated from open-hearth furnaces, basic oxygen furnaces and hot scarfing operations. The suspended particles are very fine, red in color, and are principally iron oxide (Fe_2O_3); the effluent volumes may range from 600 to 2000 gallons per minute, depending upon the type of washer used.

4. Steel Casting and Hot Rolling Mill Wastewaters

Wastewaters from continuous casting and hot rolling mill operations result from washing scale from the surface of the steel with water and in the water used to transport the scale through the flume beneath the mill line; the water used to cool the rolled product becomes part of the mill effluent. The effluents from hot mills contain suspended

particles of scale and oils which originate in the hydraulic and lubricating systems. The scale particles range from large pieces to sub-micron sizes, depending upon the particular operation and are mixtures of the various iron oxides; the oils in such effluents are only slightly water-miscible and appear as flotant oil. Effluent volumes range from 2,000 to 7,000 gallons per minute from primary mills to 5,000 to 25,000 gallons or more per minute from finishing mills. Some of the newest wide hot-strip mills produce effluents of as much as 100,000 gallons per minute.

5. Wastewaters from Cleaning Operations

Steel cleaning operations produce both acidic and alkaline solutions; spent pickling solutions and acid rinsewaters represent by far the most significant of these wastes. Spent pickling solutions from continuous strip picklers contain 5 to 9 per cent free acid and 13 to 16 per cent iron salts; from batch operations, such solutions contain 0.5 to 2.0 per cent free acid and 15 to 22 per cent iron salts. Ten to 15 per cent of the acid used in pickling is discharged in the rinsewaters as highly diluted free acid and iron salts. Sulfuric acid is used in most pickling operations and hydrochloric acid is the next most widely used. Nitric, phosphoric and hydrofluoric acids are also used in pickling stainless steels. These acids and their respective iron salts appear in spent pickling solutions and in acid rinsewaters; various additive organic chemicals and trace metals other than iron are also found. Effluent volumes from pickling tanks range from 5000 gallons per day from small batch picklers to 150,000 gallons per day from large continuous strip picklers; acid rinsewaters amount to 15 to 20 times the volumes of the strong solutions.

Alkaline cleaning solutions utilize caustic soda, soda ash, silicates, and phosphates to remove rolling oils prior to finishing operations. Spent solutions contain saponified oils and dirt and considerable residual alkalinity. Total volumes are small, ranging from 1,000 to 10,000 gallons per week; rinsewaters are very dilute solutions and are typically of the order of 100 gallons per minute per line.

6. Steel Finishing Wastewaters

Steel finishing operations consist of cold rolling, tinplating, galvanizing, plating with other metals, coating, and tempering. The effluent from a cold mill typically contains 200 mg per liter of oil, 25 percent of which is as a stable emulsion and relatively low concentrations of scale particles; effluent volumes are typically 1000-1500 gallons per minute per mill. Electrolytic tinplating solutions contain sodium stannate, sodium hydroxide, and sodium acetate; wastewater effluents result from rinsing and quenching operations and typically amount to 2,800 gallons per minute in volume. Wastewaters from other finishing operations are small in volume and are generally only contaminated in that they are heated.

7. Coke Plant Wastes

Wastewaters from coke plants originate as ammonia still wastes, coke quenching effluents, light oil plant decant waters, and acid washing effluents. Much of the wastewater is used in quenching coke and then volitalizing much of the waste material; this results in a significant air pollution problem, but the effects are usually confined to plant property. Coke plant wastes contain phenols, ammonia, ammonium salts, cyanides, chlorides, and sulfates. These wastes typically amount to 160,000 gallons per day from a single plant.

C. Re-Use of Process Water in 1964

According to the U. S. Bureau of the Census, Census of Manufacturers, the gross water intake by the industry in 1964 was 3,815 billion gallons. Gross water use, including recirculation or reuse was 5,510 billion gallons, water taken in for process purposes amounted to 867 billion gallons. The total water reused was thus 42.1 percent of the total taken in.

Steel production in 1964 amounted to 127,076,000 ingot tons. Hot-rolled products totaled 93,635,000 tons and steel produced as cold-rolled sheets and strips, cold-rolled bars, tinplate and terneplate, and galvanized sheets and strip totaled 33,030,000 tons. Blast furnace production totaled 86,212,000 tons and was accomplished in 147 furnaces. Steel was produced as follows:

Steelmaking Process	Production, tons
Open Hearth	98,097,000
Bessemer	858,000
Electric Furnace	12,678,000
Basic Oxygen Furnace	15,442,000

Industrial Wastewater Control, Academic Press, New York, 1965 tabulates the following water requirements in steelmaking operations:

Department of Mill	Gal. per ton of Finished Steel	Percent of Total
Blast Furnace	10,000	25
Open Hearth	5,000	12 1/2
Coke Plants	5,000	12 1/2
Hot Mills	10,000	25
Finishing Mills	8,000	20
Sanitary, Boiler, Etc.	2,000	5
	40,000	100

Process water may be defined in the steel industry as water which contacts the product or any by-product, including fumes and gases generated by the process. Cooling water may be defined as water, used for cooling, which does not directly contact the product or any process by-product. These definitions are conventional within the industry, at least with people concerned with pollution problems. Such definitions are reasonable in that most water-washing operations in the industry do result in the recovery of some useful material of value.

Dust Recovery Practice at Blast Furnaces, Ohio River Valley Water Sanitation Commission, 1958 indicates that about 3200 gallons of water per ton of iron produced is used for gas-washing purposes. Process water use in blast furnaces in 1964 is thus estimated to have been 86,212,000 x 3,200, or 276 billion gallons; cooling water use was thus about 86,212,000 x (10,000-3,200), or 586 billion gallons.

Only a few open hearth furnaces were equipped with wet-washers in 1964; the water used in the open-hearth is primarily for cooling. The cooling water used for open-hearth cooling in 1964 is estimated to have been 98,090,000 x 5,000, or 491 billion gallons; process water use was minimal.

All basic oxygen furnaces have been built with gas-cleaning facilities. A typical furnace uses 2,200 gallons of water per minute for initial scrubbing of the exit gases and 10,000 gallons per minute for final cooling of these gases; it may produce 250 tons of steel per hour. In 1964 the average capacity of a basic oxygen furnace was 700,000 tons per year. Assuming 22 operating furnaces of average capacity, process water use was 530 gallons per ton and cooling water use was 2400 gallons per ton. Total process water use was thus about 15,442,000 x 530, or 8.2 billion gallons and cooling water use about 37.1 billion gallons.

Few electric furnaces use water scrubbers for fume control. Cooling water requirements may be estimated as for open-hearth furnaces. This use amounted to about 12,678,000 x 5,000, or 63.4 billion gallons in 1964; a minimal amount was used as process water.

About one-half of the water used in a hot-mill is used as cooling water in the reheating furnaces; the remainder is used to wash scale from the steel and for flume flushing. The process water use in hot rolling was then about 93,635,000 x 5000, or 468 billion gallons and the cooling water an equal amount. The water used in a finishing mill and its related processes is all process water; such use in 1964 was about 33,030,000 x 8000, or 264 billion gallons.

Approximately 99% of the water used in a coke plant is for cooling and is estimated to have aggregated 127,076,000 x 4,950, or 632 billion gallons in 1964. Process water use was thus about 127,076,000 x (5,000-4,950), or 6.4 billion gallons.

Sanitary, boiler, etc. uses would have been about 127,076,000 x 2,000, or 254 billion gallons in 1964. The remaining water uses in a steel mill are for blowers, condensers, and miscellaneous coolers and may be taken to be the difference between the sum of all the uses detailed above and the total used, i.e., about 1,955 billion gallons in 1964.

The various water uses in the industry in 1964 are summarized below.

INDUSTRY WATER USES IN 1964, BILLIONS OF GALLONS

Manufacturing Process	Process Water	Cooling Water
Blast furnaces	276	586
Open hearth furnaces	1	491
Basic oxygen furnaces	8	37
Electric furnaces	1	63
Hot-rolling mills and related	468	468
Cold mills and related	264	-
Coke plants	6	632
Sanitary, boiler, etc.	-	254
Blowers, condensers, etc.	-	1955
	1024	4486

On the basis of the above, process water reuse in 1964 was about 157 billion gallons; this amounts to 18.1% of the water taken in for such purposes. Cooling water reuse is indicated to have been 1,538 billion gallons, or 52.2% of the water taken in for such purposes.

D. Industry Subprocesses and Mix

The various fundamental manufacturing processes in the steel industry may be carried out by alternative means in most cases. For the purposes of this study the alternative means have been designated subprocesses. The steel industry is so heterogeneous that almost any combination of these subprocesses can be found in any one plant, depending upon the products manufactured and the source of the plant's raw materials. The subprocesses which may be included under ironmaking are those which are normally operated by the blast furnace department in an integrated steel mill. For this reason sinter plants are included herein.

1. Ironmaking

Molten iron for subsequent steelmaking operations is normally produced in a blast furnace. The blast furnace is a vertical, quasi-cylindrical

structure, ranging from 65 to 106 feet high and 15 to 28 feet in diameter. The blast furnace process consists essentially of charging iron ore, limestone, and coke into the top of the furnace and blowing heated air into the bottom. Combustion of the coke provides the heat necessary to obtain the temperature at which the metallurgical reducing reactions take place. Incandescent carbon of the coke accounts for about 20% of the reduction of the iron oxides; carbon monoxide formed between the coke and oxygen of the blast accounts for the remaining reduction accomplished. The function of the limestone is to form a slag, fluid at the furnace temperature, which combines with unwanted impurities in the ore. Two tons of ore, one ton of coke, one-half ton of limestone, and three and one-half tons of air produce approximately one ton of iron, one-half ton of slag, and five tons of blast furnace gas containing the fines of the burden carried out by the blast; these fines are referred to as flue dust. Molten iron is periodically withdrawn from the bottom of the furnace; the fluid slag which floats on top of the iron is also periodically withdrawn from the furnace. Blast furnace flue gas has considerable heating value and is burned to preheat the air blast to the furnace.

The blast furnace auxiliaries consist of the stoves in which the blast is preheated, the dry dust catchers in which the bulk of the flue dust is recovered, primary wet cleaners in which most of the remaining flue dust is removed by washing with water, and secondary cleaners such as electrostatic precipators.

a. Hot Metal Production

When molten iron is used directly from the blast furnace, the furnace is said to be producing hot metal. Hot metal for steel production is occasionally produced in a hot blast cupola. The cupola resembles a miniature blast furnace; it differs from the blast furnace in that pig iron and steel scrap replace iron ore in the charge. Coke and limestone are used to provide the fuel and fluxing agents.

b. Pig Iron Manufacture

Iron from the blast furnace, instead of being used in the molten state, is sometimes cast into 100 pound blocks known as pigs - hence the term pig iron for the blast furnace product. Pig iron is produced in this form in cases where the hot metal cannot be immediately utilized in an integrated mill and is almost always produced in this form by merchant blast furnaces.

c. Silvery Pig Iron Manufacture

Silvery pig iron is produced in a blast furnace which is charged with high silicon content ores. Silvery pig iron contains about 10%

silicon and is used in steelmaking processes to lessen the tendency of iron to "chill" and to offset the hardening affect of manganese.

d. Ferroalloy Manufacture

The ferroalloys other than ferrosilicon (silvery pig) include spiegeleisen, ferromanganese, and ferrophosphorous. These materials are made in a blast furnace using ores high in content of the metals desired. These materials are used as alloy elements in the manufacturing of steel. It is more common today to produce ferroalloys in electric furnaces rather than in blast furnaces, but blast furnace production of these materials is still substantial.

e. Sinter Plant Operation

Fine ores must be converted to a lump form my some process of agglomeration before they can be effectively used in the blast furnace. There are several methods of accomplishing this end: sintering, modulizing, pelletizing, and briquetting. Sintering is the principal method used today and is used to reclaim flue dust and mill scale for recharging into production processes, as well as to agglomerate fine ores. In sintering, fine material is mixed with a pulverized fuel and placed on a grate where the mixture is burned to a clinker under a forced draft.

2. Steelmaking

Most of the steel produced in the United States is made in open-hearth furnaces, the open-hearth is, however, rapidly giving way to the newer basic oxygen process. A considerable tonnage of steel is produced by electric furnaces, especially alloy and specialty steels. The Bessemer process, the original of the modern steelmaking methods, produces only a small percentage of the total today.

a. Open-Hearth Furnaces

The open-hearth furnace consists essentially of a shallow rectangular basin or hearth enclosed by walls and roof, all constructed of refactory brick, and provided with access doors along one wall adjacent to the operating floor. A tap hole at the base of the opposite wall is provided to drain the finished molten steel into ladles. Fuel is burned at one end, the flame traveling the length of the furnace above the charge resting upon the hearth. Upon leaving the furnace, the hot gases are conducted in a flue, downward into a regenerative chamber called checkerwork; this mass of refactory brick is laid to provide a large number of passage ways

for the hot gases. Heat is thus stored in the checkers and is subsequently given up to a reverse direction stream of air flowing to the burners. Open-hearth furnace capacities span a wide range from 100 to 300 tons per heat; the time required to produce a heat is between 8 and 12 hours.

The open-hearth process consists of several stages: tap to start, charging, melt down, hot met . addition, ore and lime boil, working (refining), tapping, and delay. The raw materials to the open-hearth process consist of pig iron, iron ore, limestone, scrap iron, scrap steel, hot metal, and various alloying substances. The object of the operation is to reduce the impurities present in the scrap and pig iron to the limits specified for the different qualities of steel. The refining operation is carried out by means of a slag that forms a continuous layer on the surface of the liquid metal.

The injection of gaseous oxygen into the bath during the refining period speeds the oxidation reactions, shortens heat time, saves fuel, and increases production rates; this practice has become more or less standard in the last decade, and has extended the technological life of the open-hearth process.

b. Electric-Arc Furnaces

Electric furnaces range in size from 7 to 30 feet in diameter and produce from 2 to 200 tons of steel per cycle, a cycle requiring 1.5 to 4 hours. The electric furnace is uniquely adaptable to the production of special alloy steels, however, almost one-half of electric furnace production is carbon steel.

The cycle in electric furnace steelmaking consists of the meltdown, the molten-metal period, the boil, the refining period, and the pour. The required heat is generated by an electric arc passing from the electrodes to the charge in the furnace. The refining process is similar to that of the open-hearth, but more precise control is possible in the electric furnace. Use of oxygen in the electric furnace has been common practice for many years.

c. Basic Oxygen Furnace

Vessels for the basic oxygen process are generally vertical cylinders surmounted by a truncated cone. High-purity oxygen is supplied at high pressure through a water-cooled tube mounted above the center of the vessel. Scrap and molten iron are charged to the vessel and a flux is added. The oxygen lance is lowered and oxygen is admitted. A violent reaction occurs immediately and the resultant turbulence brings the molten metal and the hot gases into intimate contact, causing the impurities to burn off quickly. An oxygen blow of 18 to 22 minutes is normally sufficient to refine the metal. Alloy additions are made and the steel is ready to be tapped.

A basic oxygen furnace can produce 200 to 300 or more tons of steel per hour and allows very close control of steel quality. A major advantage of the process is the ability to handle a wide range of raw materials. Scrap may be light or heavy, and the oxide charge may be iron ore, sinter, pellets or mill scale.

d. Bessemer Converter

Bessemer converters are cylindrical vessels in which the molten metal charged is subjected to a stream of air passed up vertically from the bottom. The air blast literally burns the impurities out of the metal. The Bessemer converter can produce 25 to 60 tons of steel in 10 to 30 minutes. The quality of the steel produced is difficult to control and the converters can only handle limited amounts of scrap.

3. Steel Casting

Ingot molding and subsequent reheating operations remain the principal means of readying steel for further processing in this country. The continuous casting of slabs and billets is, however, being rapidly developed and translated into commercial operation.

a. Ingot Molding and Conditioning

Following the refining operation in the open-hearth, Bessemer converter, electric, or basic oxygen furnace, the molten steel is poured from the furnace into a ladle and subsequently into a mold. The solidified steel castings are called ingots. Before these ingots are rolled, the metal is allowed to solidify throughout. The heat supply is carefully manipulated to bring the whole body of metal to a uniform rolling temperature in a kind of heating furnace known as a "soaking pit."

b. Continuous Casting

Continuous casting involves pouring molten steel through a vertical cooling chamber and withdrawing the solidified shape from the bottom of the mold in a continuous piece. The slab or billet shape thus formed is withdrawn through a series of rolls, straightened, and cut into suitable lengths. The molds are made of copper, abrogated from a solid block or by assembling plates, and are cooled by the internal circulation of copious amounts of water. Only a small amount of solidification takes place in the mold and water sprays below the mold perform the major cooling of the exposed casting. Other shapes such as small rounds have been successfully cast by this technique; stainless, tool, alloy, and carbon steels all have

been successfully cast continuously. The major advantage of continuous casting is, of course, the direct production of semi-finished shapes ready for the final rolling operations into finished products. The soaking pit and primary rolling operations are eliminated and production rates can be maintained at the very high levels permitted by the modern steelmaking processes.

4. Hot-Rolling Mills

Hot-rolling mills exist in a bewildering variety that makes simple classification and description difficult. In general, primary mills reduce ingots to slabs or billets; secondary or finishing mills reduce slabs or billets to plates, shapes, strip, etc.

a. Primary Rolling Mills

It is possible, and often economical, to roll ingots directly through the bloom, slab, or billet stages into more refined and even finished steel products in one mill in a continuous operation, frequently without any reheating. Large tonnages of standard rails, beams, and plates are produced regularly by this practice from ingots from medium to large size. Most of the ingot tonnage, however, is rolled into blooms, slabs, or billets in one mill following which they are cooled, stored and eventually rolled in other mills or forged.

The basic operation in a primary mill is the gradual compression of the steel ingot between the surfaces of two rotating rolls, and the progression of the ingot through the space between the rolls. The physical properties of the ingot prohibit making the total required deformation of the steel in one pass through the rolls, so a number of passes in sequence are always necessary. As the ingot enters the rolls, high pressure water jets removes surface scale. The ingot is passed back and forth between the horizontal and vertical rolls while manipulators turn the ingot from time to time so that it is well worked on all sides. When the desired shape has been achieved in the rolling operation, the end pieces or crops are removed by electric or hydraulic sheares. The semifinished pieces are stored or sent to reheating furnaces for subsequent rolling operations.

b. Semifinished Steel Preparation

Ever increasing attention is being devoted to the conditioning of semifinished products as the requirement for high qualities of steel products increases. Major elements in this area involves the need for removing surface defects of blooms, billets, and slabs prior to shaping, as by rolling into a product for the market. Such defects as rolled seams, light scabs, checks, etc., generally retain their identity during subsequent forming processes and result in products of inferior quality.

These surface defects may be removed by hand chipping, machine chipping, scarfing, grinding, milling, and hot steel scarfing. The various mechanical means of surface preparation are those common in all metal working and machine shop operations. Scarfing is a process of supplying streams of oxygen as jets to the surface of the steel product under treatment, while maintaining high surface temperatures that results in rapid oxidation and localized melting of a thin layer of the metal. The process may be a manual one consisting of the continuous motion of an oxyacetylene torch along the length of the piece undergoing treatment. In recent years the so-called hot scarfing machine has come into wide use. This is a production machine adapted to remove a thin layer (1/8 inch or less) of metal from all four sides of red hot steel billets, blooms, or slabs as they travel through the machine in a manner analogous to the motion through rolling mills.

c. Reheating Furnaces

Reheating is necessary throughout the rolling operation whenever the temperature of the metal being worked falls below that necessary to retain the required plasticity. Reheating furnaces are of two general classes, batch and continuous types. Bath furnaces are those in which the charged material remains in a fixed position on the hearth until heated to rolling temperature. Continuous furnaces are those in which the charged material moves through the furnace and is heated to rolling temperature as it progresses toward the exit. One unique type of reheating furnace is the rotary hearth type used frequently for heating rounds in tube mills and for heating short lengths of blooms or billets for forging. The rotary hearth type permits external walls and roof to remain stationary while the hearth section of the furnace revolves. Batch furnaces vary in size from those with hearths of only a few feet square to those 20 feet in depth by 50 feet long; some modern continuous furnaces have hearths 80 to 90 feet long.

d. Plate Mills

Plates are classified, by definition, according to certain size limitations to distinguish them from sheet, strip, and flat bars. According to this classification plates are generally considered to be those flat hot-rolled finished products that are more than 8 inches wide and generally 1/4 inch or more thick. Sequence of operations for plate mills is heating of slabs, descaling, rolling, leveling, cooling, and shearing. Most plate mills use continuous type heating furnaces. Descaling in modern plate mills is accomplished by hydraulic sprays impinging on both top and bottom surfaces and operated at pressures up to 1500 pounds per square inch. Temperature variation in the plate from the front to the back is a problem of particular importance in rolling plates as is the care that must be exercised in cooling the

rolled product so as to avoid distortion. Plate rolling mills are generally considered in two very broad design classifications. One type includes the universal mills which are characterized by vertical rolls preceding and following the horizontal rolls; such a mill produces a product of the width which conforms to narrow tolerances. The second general type of mill is the sheared plate mill which may or may not include edge working equipment.

e. Structural and Other Shape Mills

A wide variety of various steel shapes are rolled from blooms; these shapes include structural sections such as I-beams, channels, angles, wide flanged beams, H-beams, sheet piling, rails, and numerous special sections. The heating of the bloom for large sections is usually done in the batch type furnace, although some newer mills use continuous furnaces. A typical mill consists of a two high reversing breakdown stand in which initial shaping is accomplished followed by a group of three roll stands in train where the rolling process is completed; these mills are known as roughing stands, intermediate stands, and finishing stands. Several passes of the material is made back and forth through the breakdown roughing and intermediate mills; a single pass is usually made through the finishing stand. The sequence of operations then consists of heating bloom, rolling to proper contour dimensions, cutting while hot to lengths that can be handled, cooling to atmospheric temperature, straightening cutting to ordered lengths, and shipping.

f. Merchant-Bar, Rod and Wire Mills

Merchant-bar, rod, and wire mills produce a wide variety of products in continuous operations ranging from shapes of small size through bars and rods. The designations of the various mills as well as the classification of their products are not very well defined within the industry; in general, the small cross-sectional area and very long lengths distinguish the products of these mills. Raw materials for these mills are reheated billets. Many older mills use hand looping operations in which the material is passed from mill stand to mill stand by hand; newer mills use mechanical methods of transferring the material from stand to stand. As with other rolling operations the billet is progressively squeezed and shaped to the desired product dimensions in a series of rolls. Water sprays are used throughout the operation to remove scale.

g. Hot-Strip Mills

The continuous hot-strip mill utilizes slabs which are brought to rolling temperatures in continuous reheating furnaces; the conditioned slabs pass through scale breakers and high pressure water sprays which

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dislodge the loosened scale. A series of roughing stands and a rotary crop shear produce a section that can be finished to a coil of the proper weight and gauge. The second scale breaker and high pressure water sprays precede the finishing stand train in which the final size reductions are made. Cooling water is applied through sprays on the run out table, and the finished strip is coiled. Such a mill can turn a thick 6 foot slab of steel into a thin strip or sheet a quarter of a mile long in 3 minutes or less. The modern hot strip mill produces a product which may be up to 96 inches wide, although the most common width in newer mills is 80 inches. The product of the hot-strip mill may be sold as produced, or used within the mill for further processing in cold reduction mills, and for tin-plated or galvanized products.

h. Pipe and Tube Mills

Welded tubular products are made from hot-rolled skelp with square or slightly beveled edges, the width and thickness of the skelp being selected to suit the various sizes to be made. The coiled skelp is uncoiled, heated, and fed through forming and welding rolls where the edges are pressed together at high temperature to form a weld. Welded pipe or tube can also be made by the electric weld process, where the weld is made by either fusion or resistence welding.

Seamless tubular products are made by rotary piercing of a solid round bar or billet followed by various forming operations to produce the required size and wall thickness.

5. Steel Cleaning

Correct surface preparation is the primary and most important requirement for satisfactory application of protective coatings to steel. Without a properly cleaned surface, even the most expensive coatings will fail to adhere or to prevent rusting of the steel base. A variety of cleaning methods are utilized to insure good surface preparation for subsequent coating. The steel surface must also be cleaned at various stages during production to insure that oxides formed on the surface are not worked into the finished product causing marring, staining, or other surface blemish.

a. Pickling

Pickling is the process of chemically removing oxides and scale from the surface of the steel by the action of water solutions of inorganic acids. While pickling is only one of several methods of removing undesirable surface oxides, this method is the most widely used in the manufacture of sheet and tin mill products, due to comparatively low operating cost and ease of operation.

Some products such as tubes and wire are pickled in batch operations; that is, the product is immersed in an acid solution and allowed to remain in this solution until the scale or oxide film is removed The material is lifted from the bath, allowed to drain, and rinsed by sequential immersion in rinse tanks.

Pickling lines for hot-rolled strip operate continuously on coils that are welded together, passed through the pickler, then sheared and recoiled. The steel passes through the pickler countercurrently to the flow of the acid solution. Most mild steel is pickled with sulphuric or hydrochloric acid; stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids. Various organic chemicals are used in pickling to inhibit acid attack on the base metal, while permitting preferential attack on the oxides; wetting agents are used to improve the effective contact of the acid solution with the metal surface. As in the batch operation the steel passes from the pickling bath through a series of rinse tanks.

b. Solvent Cleaning

Solvents clean metal surfaces by dissolving and diluting foreign matter such as oil, grease, soil, and drawing and cutting compounds. Oil or grease may be removed by wiping or scrubbing the surface with rags or brushes wetted with solvent, with the final wiping with clean solvent and clean rags or brushes. The steel may also be completely immersed in the solvent, or solvent sprays may be used, or the steel may be subjected to vapor degreasing in equipment in which vaporized solvent condenses on the surfaces to be cleaned. Solvents used include mineral spirits, naphthenes, and some chlorinated hydrocarbons.

c. Alkaline Cleaning

Alkaline cleaners are used where mineral and animal fats and oils must be removed. Mere dipping in solutions of various compositions, concentrations, and temperatures are often satisfactory. The use of electrolytic cleaning may be advisable for large scale production or where this method yields a cleaner product. Caustic soda, soda ash, alkaline silicates, and phosphates are common alkaline cleaning agents. Sometimes the addition of wetting agents to the cleaning bath will facilitate cleaning.

d. Blast Cleaning

Blast cleaning utilizes abrasives such as sand, steel, iron grit, or shot which impinges at high velocity against the surfaces to be cleaned, either by compressed air in nozzle type blast cleaning apparatus, or by centrifugal force and rotary type blast cleaning machines. Such methods usually result in a roughened surface and

the degree of roughness must be regulated to be satisfactory for the intended use. Newer methods of blast cleaning are said to produce smooth finishes and, as such, promise to substitute for pickling as a cleaning method.

6. Steel Finishing

Steel finishing operations involve a number of processes which do little to alter the dimensions of the hot-rolled product, but which impart desirable surface or mechanical characteristics to the product. Such processes include cold rolling, cold reduction, cold drawing, tinplating, galvanizing, coating with other metals, coating with organic compounds as well as inorganic compounds, and tempering.

a. Cold Reduction and Cold-Rolling Mills

Cold reduced, flat rolled products are made by cold-rolling pickled strip; the thickness is reduced 25 to 99% in this operation and a smooth, dense surface is produced. The product may be sold as cold reduced, but is usually heat treated. Cold reduction generates heat that is dissipated by flood lubrication in which palm oil or synthetic oils are emulsified in water and directed in jets against the rolls and the steel surface during rolling. Cold reduced strip is cleaned with alkaline detergents solutions to remove the rolling oils prior to coating operations. Electrolysis is frequently used in such cleaning operations. Cold rolling mills are used to give steel products a smooth, lustrous finish, with little reduction in thickness.

b. Tinplating

Tinplate is made from cleaned, and pickled, cold reduced strip by either the electrolytic or hot-dip process. In this country more than 80% of the tinplate is produced by the electrolytic process; the hot-dip process is rapidly becoming obsolete as is a major tinplating method. The hot-dip process consists of passing the steel through a light pickling operation and then through the tin pot which consists of a flux, molten tin, and a bath of palm oil.

The electrolytic process utilizes tin anodes and the steel strip is made the cathode; the processes vary in the composition of the electrolyte and include acid, alkaline, and halogen solutions. Electrolytic processes consist of alkaline cleaning, rinsing, pickling, plating, rinsing, fusion, quenching, chemical treatment, rinsing, drying, and oiling in sequence. The coils are welded together to provide a continuous strip through the operation and are sheared following the plating operation. In recent years tinplate has been made in increasingly thin gauges as the industry seeks to meet competition from alternative materials, particularly for containers.

c. Galvanizing

Hot-dipped galvanized sheets are produced on either sheet or continuous lines. The process consists essentially of a light pickle in hydrochloric acid and application of the zinc coating by dipping through the pot containing molten zinc. Variations in continuous operations include alkaline cleaning, continuous annealing in controlled atmosphere furnaces, and different fluxing methods.

d. Coating

In recent years, steel products coated with various synthetic resins have become commercially important. Other steel products are produced with coatings of various metals and inorganic materials. At least one major tinplate manufacturer is currently attempting to substitute chromium plating for tinplating for the container industry. Finishing operations for stainless steel products requiring a bright finish consist of rolling on temper mills or mechanical polishing.

7. Coke Plants

There are two methods for manufacturing metallurgical coke, known as the beehive and the by-product or retort process. In the beehive process, air is admitted to the coking chamber for the purpose of burning the volatile products of the coal which will generate heat enabling the process to continue. In the by-product method, the coking chambers are airtight and the necessary heat for coking is supplied from external combustion of fuel gas. In most cases, about 40% of the gases produced by the coking are returned and used as fuel.

Today, 98% of the metallurgical coal produced is by the by-product method. Beehive ovens are used in some instances when by-product ovens cannot produce enough coke during peak production periods.

a. By-Product Coke Ovens

By-product coke ovens are long, narrow, silica-brick chambers in which the coal is coked by combustion of a fuel gas in flues built in the refractory-brick walls. While there are many modifications, these ovens consist of three main parts; the coking chambers, the heating chambers, and the regenerative chambers. The products of combustion of the flue gas and the volatile products of the coking process are kept separate. By-product ovens are constructed in batteries in which the coking chambers alternate with the heating chambers. A battery may contain from 10 to more than 100 ovens.

The large ovens which are commonly installed for the production of metallurgical coke are usually 30 to 45 feet long between doors,

6 to 15 feet high, and 12 to 24 inches in width, with a capacity for 16 to 20 tons of coal per charge. For ease in removing the coke, the ovens are sometimes tapered by 2 to 4 inches from the pusher end to the coking end.

Both ends of an oven are closed with removable doors which are lifted out of place before the coke is pushed. During the coking period, the doors are in place and any cracks between the door and its jams are sealed to prevent leakage of gas and air.

When pulverized and blended coal is dropped into the hot oven, a yellow cloud of gas is evolved. This gas and that generated as the coking process continues are collected in ducts and directed to the coal-chemicals plant for conversion or refining into many by-products. In by-product ovens, the coking of one ton of coal will produce from 10 to 16 gallons of tar and light oils, 4.5 to 8.0 pounds of ammonia, and 9,000 to 12,000 cubic feet of gas which can be used for further heating.

After the ovens are sealed, charged and leveled, the coking process begins and is usually completed in 16 to 20 hours. During this period, the ovens are continually heated by the burning of gas in the heating chamber. The coking time depends on the width of the oven and the temperatures employed, but generally average about one inch of width per hour.

Since the heat is transferred to the coal from the oven walls, coking starts at the side walls and progresses to the center of the charge. When the temperature of the coal reaches its melting point, the coke fuses together but forms a vacant space in the center and resembles two parallel slabs at the end of the coking period.

When the coking is completed, the coke is pushed from the oven by a "pusher" into a quenching car. The quench car runs on rails and is constructed to catch the coke as it spills from the oven without any loss to the ground. As soon as the oven is empty, the car is run under water sprays in the quenching tower, and the incandescent coke is quenched by spraying with a large volume of water as rapidly as possible. The coke is then dropped onto a sloping storage wharf where any local hot spots can be quenched by a hose. The coke is conveyed to a screening unit and then to storage for later use.

Coke ovens are recharged immediately in order that their temperature will not be lost. If the demand for coke decreases, production is slowed by lengthening the coking period. This is accomplished by reducing the volume of gas burned in the flues.

b. Beehive Coke Ovens

A beehive oven is a firebrick chamber built with an arched roof so

that the inside shape is that of air old-fashioned beehive. A typical oven is about 12 feet in diameter, and will hold between 5 and 10 tons of coal in a uniform layer between 18 and 24 inches deep on the floor. It is provided with a door at one side and a hole in the center of the roof.

The ovens are built in long rows, one oven beside another with a retaining wall between. A row of ovens like this is called a battery. The batteries often follow the contours of the hills in the coal fields where they are located and are built into the hillside and thus require only one retaining wall along the front.

Railroad tracks for handling coal to the ovens run along the tops and other tracks for handling the coke cars run beside the ovens. Many beehive batteries have been located close to the mines so freshly mined coal can be charged directly into the ovens. No provision for stocking or blending coal is made at a beehive plant.

The small cars from the coal mine are run along the tops of the ovens and coal is charged into an empty oven through the hole at the apex of the dome. It forms a cone-shaped pile which is leveled to a uniform layer by means of a rake or a mechanically operated leveler passed through the door. Coking is started by means of the heat retained in the walls of the oven from the previous charge of coal. New ovens are brought up to temperature by heating with coal or wood before charging.

Almost immediately after charging, gas is evolved from the coal which burns in the space between the coal and the top of the oven, and on the surface of the coal. The air for combustion is admitted through an opening at the top of the oven door. By removing or adding bricks at the opening, the quantity of air is regulated. Coking proceeds downward from the top of the charge to the floor of the oven. As the coal is heated, it becomes plastic forming a semi-fused mass throughout the oven. The cake then breaks into chunks of coke as a result of further coking and cooling. The coking time which depends largely on the depth of the layer of coal, ranges from 48 to 72 hours. As the coking proceeds, the volume of gas evolved decreases, and the size of the opening in the door is correspondingly decreased. This prevents the entrance of an excessive volume of air which would otherwise burn part of the coke and might be sufficient to cool the oven as well.

When coking is complete, the door is opened and the coke is quenched by a stream of water directed through the opening. In some cases, quenching is accomplished by a self-propelled spraying device which revolves horizontally directs jets of water uniformly over the coke surface. The quenched coke is then withdrawn from the oven manually with rakes, or by a mechanical coke-drawing machine. The coke is either loaded onto conveyors or directly into railroad cars.

The beehive ovens are becoming obsolete although they hold advantages over production by the by-product method during certain peak requirements where the high investment cost of the by-product plant cannot be justified because of long inoperative periods. The reserves of high-grade coking coals are being depleted and it is becoming economically necessary to blend these with less desirable coals for the by-product process. The beehive process produces gases which are objectional from an air pollution standpoint and the quench water, if not controlled, can result in stream pollution.

8. Industry Subprocess Mix

Expansion plans of 104 plants announced in 1966 indicate that 16% of the plants plan expansions of electric furnace capacity and additions of basic oxygen furnaces and continuous casting machines. Some 4% of the plants plan improvements to open-hearth furnaces and ingot handling facilities; 5% plan to build new blast furnaces or rebuild old furnaces at integrated mills. Six plants with limited heating and rolling facilities have stated that fully integrated facilities will be installed. One new coke plant has been announced.

Industry surveys indicate that 50% of the steel production in the United States will be made by the basic oxygen process by 1970. Electric furnace production may be expected to show a consistent rate of growth percentage-wise. Increases in the use of these processes will proportionately decrease open-hearth percentage utilization. The Bessemer process will probably disappear completely in 5 years. After 1970, utilization of the open-hearth furnace will decrease percentage-wise, but at a much reduced rate; this is evident from the capital expenditures being made on open-hearth improvements.

Blast furnace and coke plant capacity will be increased as the industry capacity is increased. New facilities will be the larger, more efficient units with older facilities being consistently retired.

The trend in steel products has been toward proportionately greater increases in light, flat-rolled products and bars and in alloy steels. Decreases, percentage-wise, are apparent in pipe and tubing and in wire production. The hot-dip tinplate production has all but disappeared; electrolytic galvanized production is steadily increasing.

Steel production by the various processes is given in the following table for the years 1955 to 1965:

Year	Total 10^6Tons	Open Hearth 10^6Tons	Open Hearth %	Electric 10^6Tons	Electric %	Basic Oxygen 10^6Tons	Basic Oxygen %	Bessemer 10^6Tons	Bessemer %
1955	117.0	105.4	90.1	8.0	6.8	0.3	0.3	3.3	2.8
1956	115.2	102.8	89.0	8.7	7.7	0.5	0.4	3.2	2.9
1957	112.7	101.6	90.2	8.0	7.1	0.6	0.5	2.5	2.2
1958	85.3	75.9	89.0	6.7	7.9	1.3	1.5	1.4	1.6
1959	93.4	81.7	87.5	8.5	9.1	1.8	1.9	1.4	1.5
1960	99.3	86.4	87.0	8.4	8.5	3.3	3.3	1.2	1.2
1961	98.0	84.5	86.2	8.6	8.8	4.0	4.1	0.9	0.9
1962	98.3	83.0	84.4	9.0	9.2	5.5	5.6	0.8	0.8
1963	109.3	88.8	81.1	10.9	10.0	8.5	8.8	1.0	0.9
1964	127.1	98.1	77.2	12.7	10.5	15.4	12.1	0.9	0.7
1965	131.5	94.2	71.6	13.8	-	22.9	17.4	0.6	0.5
1966	135.0	-	-	-	-	33.0	-	-	-

Pig iron and ferroalloy production is given in the following table for the years 1940 to 1965 with the numbers of blast furnaces in blast each year:

Year	Production, 1000 Tons	Number of Furnaces
1940	47,399	195
1945	54,919	218
1950	66,400	218
1955	79,264	206
1960	68,566	229
1963	73,715	138
1964	87,933	147
1965	90,918	191

Net shipments of steel products in selected grades are tabulated in the following table with percentages of the total for the years 1956, 1960, and 1965:

Steel Products	1965 1000 Tons	1965 %	1960 1000 Tons	1960 %	1956 1000 Tons	1956 %
Heavy Structural	6165	6.7	4836	6.8	5349	6.4
Plates	9764	10.5	6132	8.6	7715	9.3
Bars	14,371	15.5	10,514	14.8	13,095	15.7
Pipe and Tubing	7689	9.4	7053	9.9	10,198	12.3
Wire	3485	3.8	2975	4.2	3943	4.7
Hot-Dip Tinplate	127	0.1	390	0.6	950	1.1
Electrolytic Tinplate	6074	6.6	5075	7.1	4615	5.6
Hot-Rolled Sheets	10,630	11.5	7991	11.2	8791	10.6
Cold-Rolled Sheets	16,571	17.9	14,466	20.3	13,317	16.0
Hot-Dip Galvanized	4491	4.8	3057	4.3	2958	3.5
Electrolytic Galvanized	362	0.4	261	0.4	227	0.3
Total Shipments	92,666		71,149		83,251	

The utilization of the various subprocesses by individual plants has been determined from information in the current and past issue of the American Iron and Steel Institute Directory of Iron and Steel Works. This information was tabulated and analyzed by electronic data processing to produce the data in Table I for the years 1950, 1963, and 1967. Projections for the years 1972 and 1977 was made on the basis of total expected production and consideration of the announced expansion plans and industry trends discussed above.

E. Waste Control Problems

Particularly difficult waste problems arise from certain steel industry subprocesses, particularly some of the newer production methods which are geared to high-speed, high-volume outputs.

The gaswasher water from ferromanganese furnaces contain particles of sub-micron sizes which are extremely difficult to separate by sedimentation. Such furnaces also produce effluents which contain greater concentrations of cyanides than from ironmaking furnaces.

The wastewaters from basic oxygen furnaces also contain extremely fine suspended particles which are particularly difficult to separate. The effluents of wet-washers used on oxygen-lanced open-hearth furnaces are similar.

Scale-bearing wastewaters from the newer high-speed rolling mills are difficult to treat. An 80-inch strip mill produces extremely fine scale particles which do not settle out of suspension in ordinary scale pits. The fine scale can cause the effluent to appear black or red, even when the concentration of solids is low.

Effluents from cold-rolling mills contain soluble oils which are not separable by ordinary sedimentation. These emulsions are extremely stable, particularly when detergents are used to wash the product on the final roll stands.

Coke plant effluents present difficult waste control problems. Phenols and creosols can be reduced by relatively simple processes, but are further reduced to the point acceptable for discharge in most instances with great difficulty.

A general characteristic of steel industry effluents that makes for difficult waste control problems is their large volumes. Most industrial waste effluent streams are not of the magnitude found in the steel industry. A waste stream flowing at 10,000 to 25,000 gallons per minute, presents a very difficult treatment problem.

TABLE I

ESTIMATED PERCENTAGES OF PLANTS EMPLOYING SUBPROCESSES

	1950	1963	1967	1972	1977
IRONMAKING					
Blast Furnaces	52.1	47.0	49.6	50.0	50.0
Pig Iron Production	50.3	43.0	46.0	46.0	46.0
Silvery Pig Iron Production	1.8	1.3	2.9	3.0	3.0
Ferroalloy Production	5.5	2.0	2.2	2.0	2.0
Sinter Plant Operation	28.5	29.1	28.8	30.0	35.0
STEEL-MAKING					
Bessemer Converters	10.3	6.0	4.3	2.0	0
Electric Furnaces	48.9	58.3	67.5	75.0	80.0
Basic Open-Hearths	49.1	41.7	39.6	35.0	30.0
Acid Open-Hearths	7.3	6.6	3.6	1.8	0
Basic Oxygen Furnaces	0	7.3	13.7	25.0	35.0
STEEL CASTING					
Ingot Molding	47.9	49.7	51.1	50.0	40.0
Continuous Casting	0	1.3	7.9	15.0	25.0
STEEL ROLLING					
Blooming Mills	46.7	49.7	50.4	50.0	50.0
Slab Mills	10.3	15.2	20.1	22.5	25.0
Billet Mills	36.4	33.8	36.0	36.9	36.0
Plate Mills	15.2	18.5	23.0	27.0	30.0
Structural Mills	9.7	10.6	14.4	16.0	18.0
Pipe Mills	8.5	13.2	11.5	12.0	12.0
Rail Mills	6.7	4.0	4.3	4.0	4.0
Rod Mills	19.4	19.9	17.3	20.0	20.0
Bar Mills	40.0	46.4	44.6	45.0	50.0
Wire Mills	18.8	18.5	20.9	22.0	25.0
Sheet Mills	17.0	15.2	16.5	18.0	20.0
Tube Mills	4.2	9.3	10.1	12.5	15.0
Hot Strip Mills	25.5	34.4	29.5	35.0	40.0
CLEANING OPERATIONS					
Batch Pickling	24.2	17.2	14.4	15.0	15.0
Continuous Pickling	20.6	19.2	19.4	20.0	20.0
Other	0.6	2.0	0.7	3.0	5.0
STEEL FINISHING OPERATIONS					
Cold Reduction Mills	33.9	35.1	43.2	45.0	50.0
Electrolytic Tinplate	7.3	7.9	6.5	7.0	7.0
Hot-Dip Tinplate	7.3	3.3	1.4	0.5	0
Wire Tinning	1.8	2.6	2.2	2.5	3.0
Galvanizing, Hot-Dip	19.4	14.6	10.1	10.0	10.0
Galvanizing, Electrolytic	0	0.5	1.0	5.0	10.0
Coating	0	1.3	2.0	3.0	5.0
Temper Mills	6.1	7.9	8.0	9.0	10.0
COKE OVENS					
By-Product Ovens	31.5	29.1	30.9	30.0	30.0
Bee-Hive Ovens	1.8	0.7	0.7	0	0

F. Production Process Streams

The steel industry today is influenced by a rapidly accelerating rate of technological change, changes in the economic climate in the country and the world, and by increasing competition from foreign steel producers and domestic producers of substitute products.

Blast furnace operations are likely to change only in degree and detail in the immediate future. Direct reduction processes are not likely to replace the blast furnace soon in this country. Somewhat larger furnaces will probably be built; beneficiated ores will be used to a greater extent as a result of improved sintering methods; higher top pressures and blast rates, oxygen enrichment, use of powdered coal, and natural gas injection are among the practices which will become increasingly common.

The basic oxygen furnace will probably replace the open-hearth furnace as the primary steelmaking process. Continuous casting with vacuum degassing will likely take the place of the sequential operations of ingot molding, soaking pit treatment, rolling of blooms, reheating, and rolling of slabs and billets.

Increasing rates of production will undoubtedly be the guiding principle as new mills are modernized. The 80-inch strip mill is rapidly becoming the industry standard and production goals are constantly being raised on these mills. Automation of rolling mills is becoming more and more common; automatic operation of the rolling process is general, with a few mills under complete computer control. Pickling with hydrochloric acid in vertical towers, with acid regeneration, bids fair to replace much of the strip pickling solution disposal problem.

Finishing processes are constantly being developed as the steel industry looks to competition from other materials. Thin tinplate, steel foil, steel clad with other metals, and a variety of formed and coated products are among the products that foreshadow future developments.

1. Process streams are described below as if all of the manufacturing processes were carried out at each plant; this is not the case in the steel industry. Many mills, for example, operate as cold shops, i.e., they roll steel obtained elsewhere. Some plants operate only blast furnaces, with or without coke ovens, selling pig iron as their products. Plant sizes are not divided according to the numbers of or relative sizes of the various subprocesses. Small plants tend to be cold shops or merchant iron furnaces. Large plants are integrated mills. Medium plants are either large cold shops or small integrated mills.

a. Typical Production Technology

A typical integrated steel mill today has one or more blast furnaces with daily capacities of 1000 tons of iron; such furnaces operate on computerized scheduling of production and utilize venturi scrubbers for gaswashing. Such a typical mill operates a sinter plant for ore benefication and uses wet-washers to scrub the fume produced by the sintering machine.

Steelmaking is typically accomplished in oxygen-lanced open-hearth furnaces with dry type fume-reducing equipment or with no air pollution control devices. Steel casting is accomplished by ingot molding, and degassing techniques are utilized. Blooming mills and slabbing mills are utilized, as are soaking pits. Reheating is minimized by imporved handling of slabs and billets. Semifinished steel is conditioned by hand scarfing.

A typical mill produces hot-rolled strip on an 80-inch continuous mill which operates by computerized scheduling, and utilizes a wide range of plate, bar, wire, rod, and structural shape mills in which manual handling has been eliminated entirely.

Steel pickling is accomplished in high-speed, horizontal strip picklers utilizing sulfuric acid. Cold reduction mills utilize proprietary soluble oils and employ recirculation schemes which result in maximum emulsion life. Electrolytic tin-plating and galvanizing are the principal coated steel products; extensive cleaning and conditioning of the steel strip and the product is involved.

By-product coke ovens utilize beneficated coal to a large extent, reflecting the low availability of high-grade coking coals. By-products are recovered to a nominal extent; ovens are relatively old and efficiency is impaired by leaks around doors, etc., although remedial measures are taken. Coke is quenched with ammonia liquor.

b. Older Processing Technology

A steel mill utilizing older, relatively inefficient processing technologies will have one or more blast furnaces of 675 tons per day capacity, operated with manual scheduling techniques. Such furnaces will typically utilize tile and hurdle wet-washers. A sinter plant may be operated, but will generally have no air pollution control devices.

Steelmaking is accomplished in such plants in conventional open-hearth furnaces of relatively small size; no air pollution control is practiced. Steel casting is accomplished by ingot molding with no degassing provisions. Blooming mills and slabbing mills are used; soaking pits are used and extensive reheating is necessitated by

manual transportation of semifinished steel. Semifinished steel is conditioned by hand chipping and grinding.

A mill utilizing older technology may produce 31-inch wide strip at relatively slower speeds and utilize looping mills in which bars and rods are manually handled between the mill stands. Pickling may be accomplished at relatively low rates in horizontal tanks using sulfuric acid. Cold reduction mills may use palm oil to make up lubricants for flood-cooling and utilize once-through lubricating systems. Electrolytic tinplating and galvanizing are employed, but production rates may be relatively slow and cleaning operations minimal.

By-product coke ovens may be of nominal capacity and efficiency and by-product recovery may be practiced at a net cost.

c. Advanced Processing Technology

An integrated steel mill operating at an advanced level of technology has one or more blast furnaces with daily capacities of 1000 tons or more of iron; such a furnace is fully automated with raw materials fed under computer control. The furnaces will utilize venturi scrubbers for gaswashing, be charged with pellitized iron ore, and operate with high top pressures and fuel injection.

Steelmaking in advanced technology is accomplished in basic oxygen furnaces, typically equipped with wet-washers for fume control and in oxygen-lanced open-hearths similarly equipped. Steel casting is increasingly accomplished by continuous casting with vacuum degassing, but is not yet a normal production technique in the United States. Semifinished steel is conditioned by mechanical hot scarfing.

The most advanced hot-strip mills are completely automated and produce up to 96-inch wide strip at extremely high speeds. Other hot mills operate at high speeds and utilize varying degrees of automated control.

Steel pickling is accomplished in vertical towers or horizontal lines utilizing hydrochloric acid; strong pickle liquor is regenerated and returned to the operation with recovery of iron oxides. Cold reduction mills operate at high speeds, utilizing recirculated proprietary rolling oils and detergent washing on the final stands. Tinplate is produced in the newer, thinner gauges; chromium plating is utilized as a partial substitute for tin-plating. In addition to these operations, and galvanizing, steel products coated with organic and inorganic coatings are produced.

By-product coke ovens utilize beneficiated coal and have improved doors and are designed and maintained to minimize leaks. Coke is quenched with ammonia liquor and the residual effluents are biologically

treated. Conventional by-products are efficiently recovered and anhydrous ammonia may also be produced.

d. Plant Sizes and Technology Levels

There is no generally accepted standard of plant size in the industry. The categories given below are considered to be reasonable from analysis of available data; the divisions are, however, arbitrary.

Plant Size	% of Plants	Annual Capacity Ingot Tons
Small	53.9	Less than 1,000,000
Medium	15.2	1,000,000 to 2,000,000
Large	30.9	More than 2,000,000

The division of plants according to level of technology may be made on the basis of certain subprocesses which are uniquely descriptive of this parameter as follows:

Subprocess	Level of Technology
Blooming Mill	Old and Typical
Sinter Plant	Typical and Advanced
Basic Oxygen Furnace	Advanced
Continuous Casting	Advanced
Hot-Dip Tinplate	Old
Cold Reduction	Typical and Advanced
Vacuum Degassing	Advanced
Beehive Coke Ovens	Old

Considering the tabulated data on the industry subprocess mix in the light of the above assumptions, the percentages of plants in the various categories indexed by plant size and level of technology are given below.

Percentages of Plants According to Size and Technology Level (1967)

Plant Size	Level of Technology		
	Old	Typical	Advanced
Small	32.0	54.7	13.3
Medium	30.0	55.7	14.3
Large	27.9	34.9	37.2
All	30.4	48.7	20.9

II. Gross Waste Quantities before Treatment or Other Disposal

A. Gross waste quantities are estimated here before treatment or other disposal; treatment or other disposal is taken to include recirculation and re-use of wastewaters. The data are presented here as if the subprocesses were incorporated in an integrated steel mill. Plant capacity is stated in terms of ingot tons of steel produced. Blast furnace and rolling capacities are taken as 2/3 of the steelmaking capacity. Coke oven capacity is taken as equal to blast furnace capacity in terms of finished coke.

1. Waste Quantities and Wastewater Volumes

a. Typical Production Technology.

The average size plant is taken to be an integrated steel mill producing 1,500,000 ingot tons per year.

Blast Furnaces

Data on suspended solids in gaswasher water from furnaces of about 1000 tons/day capacity are given below:

Capacity Tons/Day	Solids Load Tons/Day	Wastewater 1000 Gal/Day
976	18.0	1220
1019	29.1	1420
1025	28.7	5350
902	43.6	3845
950	63.9	2704
1013	77.6	2280
995	23.0	3564
1000	17.1	5994
946	13.8	1108
919	17.8	2620

Using ammonia still and benzol plant wastes for quenching coke results in phenol loads of about 0.022 pounds per ton of pig iron produced. Cyanides may be expected to amount to about 0.028 pounds per ton of pig iron on the average, but to vary ± 100% from furnace to furnace. Fluorides vary widely in gaswasher water, ranging from 0.01 to 0.10 pounds per ton of iron and averaging 0.046 pounds per ton of iron. Ammonia in the gaswasher water may be expected to be about equal to the phenol present.

Waste loads from a group of blast furnaces producing 1,000,000 tons of iron per year, or 2740 tons per day, are estimated as follows; the wastewater volume would be 8,250,000 gallons per day.

Constituent	Daily Waste Load
Suspended Solids	91.4 Tons
Phenol	60.4 lbs.
Cyanides	76.8 lbs.
Flourides	126 lbs.
Ammonia	60.4 lbs.

A typical sinter plant produces an effluent of 1,000,000 gals/day containing 50 tons of suspended solids.

Open-Hearth Furnaces

Open-hearth furnaces are typically operated today on an interim basis; most of them are expected to be retired as basic oxygen furnaces replace them. Electrostatic precipitators and bag filters have been installed on many furnaces, but wet-washers have not generally been used. These furnaces thus do not typically produce waterborne waters.

Rolling Mills

Typical rolling mills may be expected to have waste loads and wastewater volumes as follows:

Mill	Flow, gpm	Solids ppm	Gallons/ ton steel	lbs. Solids/ Ton Steel
Blooming Mill	2,000	1,000	2,300	19.0
Slabbing Mill	7,000	5,000	720	30.0
Hot-Strip Mill	25,000	1,000	6,000	50.0
Billet Mill	2,500	2,500	1,400	29.2
Bar Mill	5,000	1,000	7,000	58.3
Hot Scarfer	2,000	5,000	1,200	50.0

A typical integrated mill has rolling facilities as follows:

Mill	% of Total Production
45" Slab Mill	77.8
80" Hot-Strip Mill	77.8
40' Blooming Mill	22.2
30" Billet Mill	13.5
21" Billet Mill	8.7
10" Bar Mill	22.2

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The slab mill feeds the hot-strip mill; the blooming mill feeds the billet mills, which in turn feed the bar mill; the hot scarfer works on the billets.

For a mill producing 1,000,000 tons per year, or 2740 tons per day, the following daily waste loads and wastewater volumes may be expected:

Mill	Production Tons/Day	Solids Load lbs./day	Wastewater Gals/day
Slab	2130	64,000	1,535,000
Hot-Strip	2130	106-500	12,800,000
Blooming	608	11,550	1,400,000
30" Billet	370	10,800	518,000
21" Billet	238	6,950	333,000
Hot Scarfer	608	30,400	730,000
		230,200	17,306,000

The total scale loss of 4.2% of the finished product and the water use of 6,310 gal. per ton compare favorably with industry averages in rolling mills.

Oil content is approximately 50 ppm in the wastewater from a hot-rolling mill and may be very much greater in cases of leaking bearings and accidental spills. The waste load of oil from the typical mill might be expected to be about 11,200 lbs/day.

Pickling Wastes

About 50% of all steel products are pickled, mostly with sulfuric acid, using about 45 pounds of acid per ton of steel. The volume of waste liquor is about 30 gallons per ton of steel; and contains about 60% of the acid as ferrosulfate; rinsewater volumes are about 80 gallons per ton of steel and contain the equivalent of 15% of the acid used. Waste loads and wastewater volumes for the typical mill may be estimated as follows:

Item	Strong Liquor	Rinsewater
Volume, Gals/day	38,300	87,600
Free Acid, (H_2SO_4) lbs./day	12,350	2,180
Combined Acid, ($FeSO_4$) lbs./day	46,000	8,100

Waste acid loads and wastewater volumes may vary by $\pm$ 35% or more from these typical values.

Cold Finishing Mills

Once-through cold mills discharge about 2500 gpm of wastewaters containing an average of 150 ppm of soluble oils and about 50 ppm of suspended solids. Water use on such mills is about 2500 gal/ton of steel rolled. Approximately 20 per cent of all hot-rolled products are cold-rolled. On the basis of these figures, the wastewater volume from cold-rolling in the typical mill might be estimated as 1,370,000 gals per day. The waste oil load would be approximately 1700 #/day and the suspended solids load about 570 #/day.

Tinplating and Galvanizing

Tinplate production is about 5% of all hot-rolled products and might thus amount to 50,000 tons per year in the typical mill. The wastes of significance from this operation are from chromic acid dip rinses and from rinses following the plating operation. Each may be expected to be about 50 gpm or 72,000 gals/day; the former may contain up to 431 ppm chromium and the latter 110 ppm tin. Waste loads thus may be about 259 #/day of hexavalent chromium as chromic acid and 66 #/day of tin as sodium stannate.

Most strip galvanizing is done by the hot-dip process. This process does not produce significant liquid effluents containing soluble metals.

Both of these operations produce wastes containing pickle liquor, soluble oils, and cleaning solutions. These quantities are small in comparison with the major waste streams.

Coke Plants

The principal liquid wastes from a by-product coke plant are ammonia still wastes, benzol plant wastes, and final-cooler water. Most coke plants use the semi-direct process for ammonia recovery; in this instance dephenolization by vapor recirculation will be assumed. One net ton of coal charged yields 1300 lbs of coke in typical American practice. On this basis, the typical plant uses one million tons of coke per year, produced from 1,540,000 tons of coal charged to the coke ovens, or 4,220 tons/day.

The following waste loads are found in the plant described above, the wastewater volume is about 12,500,000 gals/day.

Constituent	Lbs. Per 1,000 Tons Coal	Load #/Day
Phenols	48	202
Cyanides (CN)	8.7	36.7
Ammonia (N)	62	262

b. Older, Relatively Inefficient Technology

The average size plant is taken to be an integrated steel mill producing 700,000 ingot tons per year.

Blast Furnaces

Data on suspended solids in gaswasher water from furnaces of about 675 tons/day capacity are given below:

Capacity Tons/Day	Solids Load Tons/Day	Wastewater 1000 Gal/Day
750	8.2	3237
750	33.3	3269
750	11.0	1652
750	32.0	1994
675	77.1	2668
675	34.5	2016
500	0.3	1728
500	10.0	3312
600	33.2	3111
767	26.2	1575

Waste loads from a group of blast furnaces producing 500,000 tons of pig iron per year, or 1370 tons per day, are estimated as follows; the wastewater volume would be 4,990,000 gallons per day.

Constituent	Daily Waste Load
Suspended Solids	54.0 tons
Phenol	30.2 lbs
Cyanides	38.4 lbs
Fluorides	63.0 lbs
Ammonia	30.2 lbs

Open-Hearth Furnaces

Older, smaller open-hearth furnaces, typical of this technology, are the first to be retired in favor of more efficient steelmaking methods. These furnaces have generally not been equipped with air pollution control devices and thus do not generate waterborne wastes.

Rolling Mills

A mill typical of older technology might have the following rolling facilities:

Mill	% of Total Production
36" Blooming Mill	36.8
44" Slab Mill	63.2
18" Bar and Billet Mill	44.8
8"-31" Hot Strip Mills	55.2

For a mill producing 500,000 tons per year, or 1370 tons per day, the following daily waste loads and wastewater volumes may be expected:

Mill	Production Tons/Day	Solids Load Lbs/Day	Wastewater Gals/Day
Blooming	505	9,600	1,160,000
Slab	865	25,900	623,000
Bar & Billet	614	24,600	2,580,000
Hot Strip	756	30,200	2,720,000
		90,300	7,083,000

The hot-strip mill is assumed to require 3,600 gals of water per ton of steel rolled and to produce 40# scale per ton of steel rolled; hot-scarfing is not used. The indicated scale loss of 3.3% and the use of 5200 gals of water per ton, reflect older practices of fewer intermediate finishing operations and slower production rates.

Oil content of the wastewater would be 100 ppm or more, indicating a waste load of 5,890 #/day or more. Leaks and spills are more prevalent in these older installations.

Pickling Wastes

Sulfuric acid pickling is not significantly different in older installations, except that the acid and water usage per ton of steel is lower; this is due to the trend toward lighter gauge products in newer mills. It is assumed that acid and water uses in older mills is 80% of that in typical installations. Waste loads and wastewater volumes may be estimated as follows:

Item	Strong Liquor	Rinsewater
Volume, gal/day	15,300	35,000
Free Acid (H_2SO_4), #/day	4,940	870
Combined Acid ($FeSO_4$), #/day	18,400	3,240

Cold Finishing Mills

Older cold mills do not operate at as high speeds as newer mills, and do not reduce the product as much. Unit oil and water usage is thus greater on newer mills; it is assumed here that the older mills use 75% of the soluble oils and water that typical mills use per unit of product. The waste oil load is thus estimated to be 637 #/day and the suspended solids load 214 #/day from the mill in the present example; wastewater volumes would be about 514,000 gals/day.

Tinplating and Galvanizing

Older technology utilizes the hot-dip processes for the manufacture of tinplate and terne. Significant amounts of soluble metals do not occur in the water wastes from these processes. Relatively small quantities of pickle liquor, soluble oils, and cleaning solutions are discharged.

Coke Plants

Coke plant effluents from older plants do not vary significantly on a unit basis from the newer plants. The waste loads and wastewater volumes for the plant of this example, producing 500,000 tons of coke per day, would be:

Constituent	Lbs. per 1000 Tons Coal	Load #/Day
Phenols	48	101
Cyanides (CN)	8.7	18.4
Ammonia (N)	62	131

The volumes of wastewater would be about 6,250,000 gals/day.

c. Advanced Production Technology

The average size plant is taken to be an integrated steel mill producing 3,000,000 ingot tons per year.

Blast Furnaces

Data on suspended solids in gaswasher water from furnaces of greater than 1000 tons/day capacity are given below:

Capacity Tons/Day	Solids Load Tons/Day	Solids Load #/Ton/Day	Wastewater 1000 Gal/Day	Wastewater Gal/Ton/Day
1470	44.5	60.5	4320	2940
1298	39.8	61.3	2720	2090
1200	181.0	302.0	6912	5750
1130	61.9	109.5	4140	3660
1330	55.3	83.2	5940	4470
1189	39.7	66.7	4464	3760

Waste loads from a group of blast furnaces producing 2,000,000 tons of iron per year, or 5480 tons per day, are estimated as follows; the wastewater volume would be 20,700,000 gallons per day.

Constituent	Daily Waste Load
Suspended Solids	312 tons
Phenol	120.8 lbs
Cyanides	153.6 lbs
Fluorides	252 lbs
Ammonia	120.8 lbs

The sinter plant which such a mill operates would be expected to produce an effluent of 1,000,000 gals/day containing 50 tons of suspended solids.

Basic Oxygen Furnace and Open-Hearth Furnaces

The average basic oxygen furnace has a capacity of about 180 tons per heat; a heat requires about 50 minutes. One such furnace will produce about 5200 tons per day of the 8200 tons per day for the example plant. The remaining 3000 tons per day would typically be made in oxygen-lanced open-hearth furnaces producing 200 tons of steel in 8-hour heats, i.e., in 5 furnaces. Some 15% of the steel produced might be made in electric furnaces as alternative to production in open-hearth furnaces. Most electric furnaces use dry air pollution control methods. Unit fume generation is about equal to that of open-hearth furnaces.

Some typical data on basic oxygen furnaces and oxygen-lanced open-hearth furnaces equipped with venturi scrubbers are given below:

Furnace	Capacity Tons/Heat	Fume Generated	Water gpm	Solids gr/gal
BOF	65		2200	-
BOF	100	25-50 ton/day	-	-
BOF	30	13-23 ton/day	-	-
BOF	250	134 tons/day	-	-
Open-Hearth	250	1.2 tons/heat	-	-
Open-Hearth	315	3.8 tons/heat	1850	60

On the basis of these figures, the suspended solids load from a BOF may be taken as equal to 50 tons/day per 100 tons of capacity per heat, and from an oxygen-lanced open-hearth furnace as equal to 2.5 tons per day per 100 tons of capacity per heat. The estimated solid load from the BOF in the example plant is then 90 tons per day and from the 5 open-hearth furnaces is 25 tons per day. The rates of fume generation are not in direct proportion to furnace capacities, nor is the water use in a venture scrubber in direct proportion to the volume of gas treated. The water use on the BOF in the example plant is estimated to be 3000 gpm and on the open-hearth furnaces 1000 gpm; wastewater volumes are thus estimated to be 4,320,000 gals/day and 7,210,000 gals/day respectively.

Rolling Mills

A typical mill using advanced technology might be expected to have the following rolling facilities:

Mill	% of Total Production
46" Blooming Mill	28.2%
45" Slabbing Mill	62.3%
21" Billet Mill	9.5%
14" Bar Mill	4.0%
10" Bar Mill	2.2%
96" Hot Strip Mill	37.6%
80" Hot Strip Mill	56.2%

Assuming that the billets and 50% of the slabs are prepared by hot-scarfing and that the newer 96" hot-strip mill uses 8,000 gals of water per ton of steel and produced 60# of scale per ton of steel, waste loads and wastewater volumes may be estimated as follows:

Mill	Production Tons/Day	Solids Load Lbs/Day	Wastewater Gals/Day
Blooming	1,545	29,400	3,560,000
Slab	3,420	102,500	2,460,000
Billet	520	15,200	728,000
14" Bar	219	12,800	1,530,000
10" Bar	121	7,050	846,000
96" Hot-Strip	2,060	123,500	16,500,000
80" Hot-Strip	3,080	154,000	18,500,000
Hot Scarfer	2,230	111,500	2,680,000
		555,950	46,804,000

The indicated scale loss of 5.1% and the water use of 8530 gals. per ton reflect the higher rates of production in newer mills and increasing steel preparation.

Oil content, taken at 50 ppm in the washwater, would result in a daily waste load of 19,500 lbs.

Pickling Wastes

Newer pickling techniques utilize hydrochloric acid in conventional horizontal-type pickling lines or in vertical tower picklers; about 80% of steel pickling is still accomplished with sulfuric acid. Hydrochloric acid consumption is 80% or less of the sulfuric acid requirement; hydrochloric acid is, however, relatively more expensive. Pickling waste loads and wastewater volumes are estimated below for the example plant:

Item	Strong Liquor	Rinsewater
Hydrochloric Liquor		
Volume, gals/day	12,250	28,100
Free Acid (HCl), #/day	3,960	700
Combined Acid ($FeCl_2$), #/day	14,700	2,590
Sulfuric Liquor		
Volume, gals/day	61,300	140,000
Free Acid (H_2SO_4), #/day	19,750	3,490
Combined Acid ($FeSO_4$), #/day	73,500	12,950

Cold Finishing Mills

Newer cold, reduction mills reduce strip products to thinner gauges, especially for "thin" tinplate. Water use can be expected to approximate 3000 gals per ton of steel rolled with oil and solid concentrations of 150 ppm and 50 ppm, respectively. On these bases,

the wastewater volume for the example plant would be expected to be approximately 7,710,000 million gals per day, assuming that 50% of the hot-rolled strip produced in such a plant is cold-reduced. The waste oil load would be about 9,630 #/day and the solids load about 3,210 #/day.

Tinplating and Galvanizing

Tinplating wastewaters and waste loads are somewhat greater in newer mills per unit of product, due to thinner gauge products; rinsewater conservation through dragout reduction is better controlled. Overall, then, unit effluent volumes and loads may be considered the same as for typical technology. On this basis, assuming 5% of hot-rolled products are tinplated, waste loads are about 518 #/day hexavalent chromium as chromic acid and 132 #/day tin or sodium stannate and wastewater volumes about 144,000 gals/day.

Of the 5% of hot-rolled products galvanized, a newer mill might produce 20% of this amount by electrolytic methods. For the example plant, wastewater volumes might amount to 25 gpm, or 36,100 gals per day containing 70 ppm zinc and 102 ppm cyanide; the waste loads would then be about 21 #/day zinc and 30.4 #/day cyanides.

These operations produce relatively small volumes of spent pickle liquor, soluble oils, and cleaning solutions.

Coke Plants

On a unit basis, the discharge from a newer coke plant is similar to the typical example; differences are found in treatment and disposal methods.

The wastewater volume from the example plant would be expected to be about 25,000,000 gals/day with the following waste loads:

Constituent	lb per 1000 ton coal	Load, #/day
Phenols	48	404
Cyanides (CN)	8.7	73.4
Ammonia (N)	62	524

The waste loads and wastewater volumes for the subprocesses associated with each level of technology are summarized in Table II.

2. Total waste loads and wastewater volumes for typical plants of each level of technology are also summarized in Table II.

TABLE II

Subprocesses Typical of Technology Level	Wasteloads, lbs per day for Average Size Plant of Indicated Technology Level and Ingot Ton Capacity per day														Wastewater Volume (Mgd)
	Suspended Solids	Phenols	Cyanides	Fluorides	Ammonia	Lube Oils	H_2SO_4	$FeSO_4$	Emulsions	Chromium	Zinc	Tin	$FeCl_2$	HCl	
OLD TECHNOLOGY - INTEGRATED MILL PRODUCING 1915 INGOT TONS PER DAY															
Blast Furnaces	108,000	30	38	63	30										4.990
Steelmaking Processes															
Rolling Mills (Hot)	90,300					5,890									7.083
Pickling							5,810	21,640							0.050
Cold Mills	214								637						0.514
Tinplating															
Galvanizing															
Coke Plants		101	18		131										6.250
Totals	198,514	131	56	63	161	5,890	5,810	21,640	637						18.887
TYPICAL TECHNOLOGY - INTEGRATED MILL PRODUCING 4110 INGOT TONS PER DAY															
Blast Furnaces	182,800	60	77	126	60										8.250
Sinter Plant	100,000														1.000
Steelmaking Processes															
Rolling Mills (Hot)	230,200					11,200	14,530	54,100							17.293
Pickling															0.126
Cold Mills	570								1,700						1.370
Tinplating										259		66			0.144
Galvanizing															
Coke Plants		202	37		262										12.500
Totals	513,570	262	114	126	322	11,200	14,530	54,100	1,700	259		66			40.683
ADVANCED TECHNOLOGY - INTEGRATED MILL PRODUCING 8230 INGOT TONS PER DAY															
Blast Furnaces	624,000	121	154	252	121										20.700
Sinter Plant	100,000														1.000
Steelmaking Processes	230,000														11.530
Rolling Mills (Hot)	556,400					19,500									46.804
Pickling							23,240	86,450					17,290	4,660	0.242
Cold Mills	3,210								9,630						7.710
Tinplating										518		132			0.144
Galvanizing			30								21				0.036
Coke Plant		404	73		524										25.000
Totals	1,513,610	525	257	252	645	19,500	23,240	86,450	9,630	518	21	132	17,290	4,660	113.166

3. Total waste loads and wastewater volumes per unit of product for each of the levels of technology are tabulated below:

WASTE LOAD, # PER DAY PER INGOT TON PER DAY

Waste	Old Technology	Typical Technology	Advanced Technology
Suspended Solids	103	125	184
Phenols	0.069	0.064	0.064
Cyanides	0.029	0.028	0.031
Fluorides	0.033	0.031	0.031
Ammonia	0.082	0.078	0.078
Lube Oils	3.08	2.72	2.37
H_2SO_4	3.03	3.54	2.83
$FeSO_4$	11.3	13.2	10.5
Emulsions	0.332	0.414	1.17
Chromium	-	0.063	0.063
Zinc	-	-	0.0025
Tin	-	0.016	0.016
$FeCl_2$	-	-	2.10
HCl	-	-	0.565

Waste water volumes on a similar basis are tabulated below:

Technology Level	Wastewater, gals/day per ingot ton per day
Older	9860
Typical	10000
Advanced	13750

4. Total waste loads and wastewater volumes produced by the industry in 1963 are estimated on the basis of the following division of plants according to size and level of technology:

PERCENTAGE OF PLANTS ACCORDING
TO SIZE AND TECHNOLOGY LEVEL (1963)

	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	35.0	57.9	7.1	56.2
Medium	33.0	63.2	3.8	17.2
Large	30.0	45.0	25.0	26.6
All	33.3	55.4	11.3	100.0

Ingot production in 1963 was 109.3 million tons and value added in manufacture by the industry was $7,860 million dollars in 1967 dollars. The estimated waste loads and wastewater volumes in 1963 are shown in Table III.

TABLE III

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1963

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million - $ Value Added
Ingot Tons/Year	36.4×10^6	60.6×10^6	12.3×10^6	109.3×10^6	
Wastewater, Gals./Year	359×10^9	606×10^9	169×10^9	$1,134 \times 10^9$	1.44×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	3,750	7,570	2,260	13,580.00	1,728,000#
Phenols	2.51	3.88	0.78	7.17	912#
Cyanides	1.06	1.69	0.38	3.13	398#
Fluorides	1.20	1.88	0.38	3.54	450#
Ammonia	2.98	4.72	0.96	8.66	1,102#
Lube Oils	112	165	29.1	306.10	38,944#
H_2SO_4	110	214	34.8	358.80	45,649#
$FeSO_4$	412	800	129	1,341.00	170,610#
Emulsions	12.1	25.1	14.4	51.60	6,565#
Chromium	-	3.81	0.78	4.59	584#
Zinc	-	-	0.03	0.03	3.8#
Tin	-	0.97	0.20	1.17	149#
$FeCl_2$	-	-	25.8	25.80	3,282#
HCl	-	-	6.95	6.95	884#

5. Production, waste load and wastewater volumes are projected here for the years 1968, 1969, 1970, 1971, 1972 and 1977 on the basis of projected value added by the industry and the likely subprocess mix in each year. Value added is related to production as follows:

VALUE ADDED, MILLION $

Year	Current $	1967 $	Production, 10^6 tons
1963	7,425	7,860	109.3
1967	10,622	10,622	135.0
1968	11,190	11,000	138.5
1969	11,840	11,400	143.0
1970	12,520	11,850	147.5
1971	13,260	12,330	152.0
1972	14,030	12,830	157.0
1977	18,680	15,620	184.0

a.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1968)

Plant Size	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	31.9	53.8	14.3	52.5
Medium	30.0	54.8	15.2	15.5
Large	27.8	34.0	38.2	32.0
All	30.0	46.0	24.0	100.0

1968 waste loads and wastewater volumes are given in Table IV.

TABLE IV

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1968

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	41.5×10^6	63.7×10^6	33.3×10^6	138.5×10^6	
Wastewater, Gals./Year	409×10^9	637×10^9	458×10^9	$1,504 \times 10^9$	1.37×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,270	7,960	6,120	18,350.00	1,668,000#
Phenols	2.86	4.07	2.13	9.06	824#
Cyanides	1.21	1.78	1.03	4.02	365
Fluorides	1.37	1.97	1.03	4.37	397
Ammonia	3.40	4.96	2.61	10.97	997#
Lube Oils	128	173	79.0	380.00	34,545
H_2SO_4	128	225	94.2	445.20	40,473#
$FeSO_4$	469	841	349	1,659.00	150,918
Emulsions	13.8	26.4	38.9	79.10	7,191
Chromium	-	4.01	2.11	6.12	556#
Zinc	-	-	0.08	0.08	7.2#
Tin	-	1.02	0.53	1.55	141
$FeCl_2$	-	-	69.9	69.90	6,354
HCl	-	-	18.9	18.90	1,711#

b.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1969)

Plant	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	31.6	53.4	15.0	52.0
Medium	29.7	54.4	15.9	15.0
Large	27.5	33.7	38.8	33.0
All	29.0	45.0	26.0	100.0

1969 waste loads and wastewater volumes are given in Table V.

c.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1970)

Plant Size	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	31.4	52.4	16.2	51.0
Medium	29.5	53.4	17.1	15.0
Large	27.4	32.7	39.9	34.0
All	28.5	42.0	29.5	100.0

1970 waste loads and wastewater volumes are given in Table VI.

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TABLE V

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1969

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	41.5×10^6	64.4×10^6	37.1×10^6	143.0×10^6	
Wastewater, Gals./Year	409×10^9	644×10^9	510×10^9	$1,563 \times 10^9$	1.37×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,270	8,050	6,826	19,146.00	1,679,000#
Phenols	2.86	4.12	2.37	9.35	820#
Cyanides	1.21	1.80	1.15	4.16	365#
Fluorides	1.37	1.99	1.15	4.51	396#
Ammonia	3.40	5.02	2.89	11.31	992#
Lube Oils	128	175	87.9	390.0	34,289#
H_2SO_4	126	228	104.99	458.99	40,262#
$FeSO_4$	469	850	390	1,709.00	149,912#
Emulsions	13.8	26.7	43.4	83.9	7,360#
Chromium	-	4.06	2.34	6.40	561#
Zinc	-	-	.09	.09	7.9#
Tin	-	1.03	.59	1.62	142#
$FeCl_2$	-	-	77.9	77.9	6,833#
HCl	-	-	21.0	21.0	1,842#

TABLE VI

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1970

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	42.0×10^6	62.0×10^6	43.5×10^6	147.5×10^6	
Wastewater, Gals./Year	414×10^9	620×10^9	598×10^9	1.632×10^9	1.38×10^3

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,326	7,750	8,004	20,080.00	1,695,000#
Phenols	2.90	3.97	2.78	9.65	314#
Cyanides	1.22	1.74	1.34	4.30	363#
Fluorides	1.39	1.92	1.34	4.65	392#
Ammonia	3.44	4.84	3.39	11.67	985#
Lube Oils	129	169	103	401	33,840#
H_2SO_4	127	219	123	469	39,579#
$FeSO_4$	475	818	457	1,750	147,679#
Emulsions	13.9	25.7	50.9	90.5	7,637#
Chromium	-	3.91	2.74	6.65	561#
Zinc	-	-	0.11	0.11	8.9#
Tin	-	1.00	0.70	1.70	143#
$FeCl_2$	-	-	91.4	91.4	7,713#
HCl	-	-	24.6	24.6	2,076#

d.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1971)

Plant Size	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	31.2	51.7	17.1	50.0
Medium	29.3	52.7	18.0	14.5
Large	27.3	32.1	40.6	35.5
All	28.0	40.0	32.0	100.0

1971 waste loads and wastewater volumes are given in Table VII.

e.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1972)

Plant Size	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	29.8	51.4	18.8	50.0
Medium	29.0	52.3	18.7	14.0
Large	27.0	31.8	41.2	36.0
All	27.0	39.0	34.0	100.0

1972 waste loads and wastewater volumes are given in Table VIII.

TABLE VII

ESTIMATED WASTE LOADS AND WASTE WATER VOLUMES IN 1971

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	42.6×10^6	60.8×10^6	48.6×10^6	152.0×10^6	
Wastewater, Gals./Year	420×10^9	608×10^9	668×10^9	$1,696 \times 10^9$	138×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,388	7,600	8,942	20,930.00	1,697,000#
Phenols	2.94	3.89	3.11	9.94	806#
Cyanides	1.24	1.70	1.51	4.45	361#
Fluorides	1.41	1.88	1.51	4.80	389#
Ammonia	3.49	4.74	3.79	12.02	975#
Lube Oils	131	165	116	412	33,414#
H_2SO_4	129	215	138	482	39,092#
$FeSO_4$	481	803	510	1,794	145,498
Emulsions	14.1	25.2	56.8	96.1	7,794#
Chromium	-	3.83	3.06	6.89	559#
Zinc	-	-	.122	.122	9.9#
Tin	-	0.97	0.77	1.74	141#
$FeCl_2$	-	-	102.1	102.1	8,280#
HCl	-	-	27.5	27.5	2,230#

TABLE VIII

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1972

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	42.4×10^6	61.2×10^6	53.4×10^6	157.0×10^6	
Wastewater, Gals./Year	418×10^9	612×10^9	734×10^9	$1,764 \times 10^9$	137×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,367	7,650	9,826	21,843.00	1,702,490#
Phenols	2.92	3.91	3.41	10.24	798#
Cyanides	1.22	1.71	1.66	4.59	358#
Fluorides	1.39	1.90	1.66	4.95	386#
Ammonia	3.48	4.77	4.17	12.42	968#
Lube Oils	131	166	127	424	33,048#
H_2SO_4	128	217	151	496	38.659#
$FeSO_4$	479	807	561	1,847	143.959#
Emulsions	14.1	25.3	62.5	101.9	7,924#
Chromium	-	3.86	3.36	7.22	563#
Zinc	-	-	0.13	0.13	10.1#
Tin	-	0.97	.85	1.82	142#
$FeCl_2$	-	-	112	112.	8,730#
HCl	-	-	30.2	30.2	2,353#

f.

PERCENTAGES OF PLANTS ACCORDING TO SIZE AND TECHNOLOGY LEVEL (1977)

Plant Size	Level of Technology			
	Old	Typical	Advanced	All Plants
Small	28.8	48.1	23.1	46.0
Medium	28.0	49.0	23.0	12.0
Large	26.0	28.4	45.6	42.0
All	24.0	29.0	47.0	100.0

1977 waste loads and wastewater volumes are given in Table IX.

TABLE IX

ESTIMATED WASTE LOADS AND WASTEWATER VOLUMES IN 1977

Technology Level	Old	Typical	Advanced	Totals	Waste Loads and Wastewater Volumes Per Million $ Value Added
Ingot Tons/Year	44.2×10^6	53.4×10^6	86.4×10^6	184.0×10^6	
Wastewater, Gals./Year	436×10^9	534×10^9	1188×10^9	$2,158 \times 10^9$	139×10^8

WASTE	WASTE LOADS IN MILLIONS OF POUNDS PER YEAR				
Suspended Solids	4,553	6,675	15,898	27,126.00	1,736.610#
Phenols	3.05	3.42	5.52	11.99	767#
Cyanides	1.28	1.50	2.68	5.46	349#
Fluorides	1.46	1.66	2.68	5.80	371#
Ammonia	3.62	4.17	6.74	14.53	930#
Lube Oils	136	145	205	486	31,114#
H_2SO_4	134	189	246	569	36,428#
$FeSO_4$	499	704	907	2,110	135,083#
Emulsions	14.7	22.1	101	137.8	8,822#
Chromium	-	3.36	5.44	8.80	563#
Zinc	-	-	0.22	0.22	14.1#
Tin	-	0.85	1.38	2.23	143#
$FeCl_2$	-	-	181	181	11,583#
HCl	-	-	48.8	48.8	3,124#

6. There are few seasonal waste patterns of significance in the industry. Since the automobile and canning industries are very large steel users, their seasonal patterns are reflected in the steel industry insofar as strip mill and tinplate products are concerned. There are, however, substantial lags due to inventory accumulations by the users and the effects are small. Uses of steel by the building and construction industries, i.e., structural shapes and reinforcing rods reflect some seasonal patterns; thus effects, overall, are small.

III. Waste Reduction Practices

A. Processing Practices

1. The subprocesses that are alternative to one another are compared in Table X as to waste loads produced. Waste load "reductions" are given as percentage reductions from "old" technology. Since subprocesses of the newer technologies often result in increased waste loads, some "reductions" are expressed as negative numbers, i.e., increased waste loads. The figures are given on the basis of waste loads per ingot ton of plant capacity; similar types of wet-washers for air pollution control are assumed in the comparisons.

Ironmaking

The alternative subprocess here are blast furnace size, operating conditions, nature of the burden, and agglomeration practices. The effects of the first three factors are incorporated in the data developed for each technology level; the overall effect of sintering is an additive one. Newer technologies result in increased waste loads.

Steelmaking

The truly alternative subprocesses in steelmaking are the oxygen-lanced open-hearth furnace and the basic oxygen furnace. Waste loads are due to air pollution control with wet scrubbers and the newer technologies result in increased waste loads. The electric furnace is limited as an alternative steelmaking subprocess because of its generally smaller capacity and unique suitability for specialty production.

Steel Casting

The effect of continuous casting on waste loads is to reduce suspended solids and oils in the plant effluent by eliminating the blooming and slabbing mills. Scale is produced in continuous casting at a rate comparable with a billet mill and little or no oil is produced. The calculation here assumes the elimination of oils and solids from blooming and slabbing mills with the addition of scale equal to that produced by a billet mill. Billets can be continuously cast; in such cases the waste load reduction would be as much as 62.5%.

Hot-Rolling Mills

The hot-rolling subprocesses that are alternative to one another are

TABLE X

Process and Subprocesses	Waste Load Reduction Per Ingot Ton Compared with "Old" Technology (%)				
	Suspended Solids	Lube Oils	Acids	Soluble Metals	Emulsions
Ironmaking:					
Small Furnace	0				
Medium Furnace + Sinter Plant	-21.8				
Large Furnace + Sinter Plant	-55.7				
Steelmaking:					
Open Hearth	0				
O_2 Lanced O.H.	-50.0				
Electric Furnace	-25.0				
Basic O_2 Furnace	-200.0				
Steel Casting:					
Ingot Molding	0	0			
Continuous Casting	40.0	100.0			
Hot-Rolling:					
31-inch Strip Mill	0	0			
80-inch Strip Mill	-66.7	4.9			
96-inch Strip Mill	-100.0	17.2			
Primary Mills + Hand Scarfing	0				
Primary Mills + Hot Scarfing	-83.5				

Continued

TABLE X

Process and Subprocesses	Waste Load Reduction Per Ingot Ton Compared With "Old" Technology (%)				
	Suspended Solids	Lube Oils	Acids	Soluble Metals	Emulsions
Cleaning Operations:					
Sulfuric Acid Pickling			0		
Hydrochloric Acid Pickling			20.0		
Shot Blasting			100.0		
Tinplating:					
Hot-Dip Process			0	0	0
Electrolytic Process			-100.0	$-\infty$	-100.0
Galvanizing:					
Hot Dip Process			0	0	0
Electrolytic Process			-100.0	$-\infty$	-100.0

Note: Waste Reduction of ($-\infty$) indicates that subprocess under "old" technology produces no significant waterborne waste.

the varying size hot-strip mills and the use of hand scarfing or hot-scarfing. Newer technology here results in increased waste loads of solids and decreased loads of oil. Hot-scarfing is considered to add to the solids loads from slab and billet mills.

Cleaning Operations

Hydrochloric acid reduces the waste acid from pickling about 20% as compared with sulfuric acid pickling. Shot blasting, when used instead of pickling, eliminates the waterborne wastes.

Tinplating

Electrolytic tinplating produces soluble metal wastes, whereas the older hot-dip process produces none. Electrolytic lines produce more pickle liquor and emulsions due to higher speed production.

2. Blast furnaces become progressively larger and sinter plants are increasingly utilized due to the need for higher rates of production and the decreasing quality of available ores. Sintering reduces flue dust loss from blast furnaces, but increases the total plant waste load. Basic oxygen furnaces are being built to replace open-hearth furnaces; the surviving open-hearth furnaces will probably all operate with oxygen lances in the near future. Conventional open-hearth furnaces will be retired. Electric furnaces will exhibit steady, slow growth, independently of increased BOF capacity. The adoption of the newer techniques is also due to the need for higher production rates.

Continuous casting is one new subprocess that reduces waste loads. Adoption of the technique is limited by the capital expenditures required and by the fact that much development work has yet to be done on the process. Overall waste load reductions are realized due to elimination of one or more primary mills from the rolling sequence.

Hot-strip mills become larger faster and roll thinner gauges due to higher production requirements and the market demand for thinner strip. Hot-scarfing increases due to the market demand for higher quality products.

Hydrochloric acid is substituted for sulfuric acid in pickling to obtain faster pickling and to produce a better surface on the product. Shot blasting is limited as a substitute for pickling due to the investment already made in pickling facilities and due to the limitation of the technique in available machines.

Electrolytic tinplating and galvanizing replace hot-dip processes due to the higher production rates possible with the newer techniques and to the reduced plating metal used per unit of plated surface.

B. Treatment Practices

1. Treatment practices applicable to the principal wastes shown in Table II are considered here for the various subprocesses from which they originate as in "typical" technology. Efficiencies given are for proper operation of facilities; improper operations reduces efficiency by 50% or more.

a. Suspended Solids

Blast Furnaces

Suspended solids are removed by sedimentation. Solids concentration in the washer water averages 2660 ppm; sedimentation basin effluents average 165 ppm. Removal efficiency is thus about 93.8%. Additions of coagulant aids can reduce the effluent concentration to as little as 50 ppm and thus increase removal efficiency to 98.2%. Recirculation of the gaswasher water with a 20% blowdown rate could increase these removal efficiencies to 98.8% and 99.6% respectively. Sinter plant effluents are treated similarly and removal efficiencies are similar.

Rolling Mills

Suspended solids are removed by sedimentation to varying degrees in scale pits and secondary clarifiers. Removal efficiencies are calculated below, assuming an average flume water solids concentration of 1600 ppm and average scale pit effluent concentration of 150 ppm. Removal efficiency is then about 90.7%. Coagulant aids can reduce effluent concentrations by about 50%, increasing removal efficiency to approximately 95.4%. Recirculation with a blowdown rate of 1/3 might increase these removal efficiencies to 96.9% and 98.4% respectively.

Cold Mills

Suspended solids in cold mill waste streams may be reduced by recirculation of the rolling emulsion and through the use of magnetic separators. Recirculation might reduce solids by 50% and with magnetic separators or coagulation and sedimentation by 80%. Coagulation and sedimentation on the once-through effluent might reduce suspended solids by 50%.

b. Phenols, Cyanides, and Ammonia

Blast Furnaces

These constituents may be reduced by 90% if river water is used for quenching coke rather than still wastes; they would, however, alternatively appear in the coke plant effluent. Biological treatment may reduce these compounds by 80%.

Coke Plants

Phenols may be reduced by 81%, cyanides by 98%, and ammonia by 99% if coke is quenched with benzol plant wastes and still wastes and all cooling water is recirculated. These substances can be reduced 100% by deep well disposal and by 80% by biological treatment.

c. Fluorides

Blast Furnaces

Fluorides originate in the iron ore and could only be reduced by using ore from low fluoride sources.

d. Lubricating Oils

Hot-Rolling Mills

Plain sedimentation removes less than 20% of effluent oil using belt or cylinder type oil removal devices. The use of coagulation and sedimentation may result in oil removal efficiencies of 80%. With recirculation, oil removal efficiencies may be 60% using belt or cylinder type oil removal devices and 90% or better with coagulation and sedimentation.

e. Emulsions

Cold Finishing Mills

Emulsified oils in cold mill effluents may be redued by 75% by recirculation of the soluble oil solutions. Treatment by means of coagulation and flotation may reduce the waste load by 95%.

f. Soluble Metals

Plating Operations

These substances can be removed with efficiencies of 95% by ion exchange methods, followed by treatment of the resin regenerant solution. These substances can be reduced 100% by deep well disposal.

g. Waste Acids

Pickling Solutions

Pickling solutions can be disposed of by injection in deep wells. This results in 85% removal efficiency if the strong liquor is thus disposed of; it is not economically feasible to dispose of rinsewater in this manner. Neutralization of spent pickle liquor with lime reduces the waste load insofar as free acid and dissolved iron are concerned, but adds the calcium salt of the acid. The reduction of the waste load from sulfuric acid pickling is about 80%, considering the calcium salt residual and the fact that rinsewaters are not neutralized. Regeneration processes can recover the acid and iron from strong pickle liquor with about 95% efficiency; overall efficiency is then about 80%. The relatively small amounts of alkaline wastes generated act to neutralize acid wastes and thus constitute a treatment practice of sorts.

h. Summary

Removal efficiencies of the various waste treatment methods are summarized in Table XI.

2. The estimated percentages of plants employing the various treatment practices are summarized in Table XII.

a. There are few of these treatment practices which must be employed in any particular sequence due to technological considerations. Plain sedimentation of blast furnace gaswasher water and of mill scale has preceded other techniques, principally because some such removal is necessary to permit utilization of blast furnace gas and to prevent sewer clogging. The considerations involved in choosing the sequence in which removal practices are employed are economic in nature, seldom technological.

TABLE XI

Removal Method & Source of Matter	Normal Removal Efficiency for Indicated Waste: Suspended Solids	Lube Oils	Acids	Soluble Metals	Emulsions	Coke Plt. Chemicals
I. Plain Sedimentation:						
A. Blast Furnace & Sinter Plt.	93.8					
B. Hot-Rolling Mills	90.7	20.0				
II. Coagulation & Sedimentation:						
A. Blast Furnace & Sinter Plt.	98.2					
B. Hot-Rolling Mills	95.4	90.0				
C. Cold Mills	50.0					
III. Recirculation and:						
A. Plain Sedimentation:						
1. Blast Furnace & Sinter Plt.	98.8					
2. Hot-Rolling Mills	96.9	60.0				
3. Cold Mills	50.0				75.0	
B. Coagulation & Sedimentation:						
1. Blast Furnace & Sinter Plt.	99.6					
2. Hot-Rolling Mills	98.4	90.0				
3. Cold Mills	80.0				95.0	
C. Magnetic Separators	80.0					
IV. River Water for Coke Quenching:						
A. Blast Furnace						90.0
V. Still Wastes for Coke Quenching:						
A. Coke Plant						92.7
VI. Biological Treatment						90.0
VII. Deep Well Disposal			85.0	100.0		100.0
VIII. Ion Exchange				95.0		
IX. Neutralization & Sludge Lagooning			80.0			
X. Regeneration Processes			80.0			
XI. Proper Operation of Facilities						

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TABLE XII

Removal Method & Source of Wastes	Estimated Percentage of Plants Employing Method 1950	1963	1967	1972	1977
I. Plain Sedimentation					
A. Blast Furnace & Sinter Plant	93	85	80	60	40
B. Hot-Rolling Mills	87	78	68	55	40
II. Coagulation & Sedimentation					
A. Blast Furnace & Sinter Plant	0	4	5	15	25
B. Hot-Rolling Mills	0	1	2	5	10
C. Cold Mills	0	2	4	6	8
III. Recirculation and:					
A. Plain Sedimentation					
1. Blast Furnace & Sinter Plt.	5	8	10	15	20
2. Hot-Rolling Mills	10	15	20	25	30
3. Cold Mills	50	65	70	65	60
B. Coagulation & Sedimentation					
1. Blast Furnace & Sinter Plt.	2	3	5	10	15
2. Hot-Rolling Mills	3	6	10	15	20
3. Cold Mills	10	15	20	25	30
C. Magnetic Separators	5	10	15	20	30
IV. River Water for Quenching Coke					
A. Blast Furnace	80	50	20	10	10
V. Still Wastes for Quenching Coke					
A. Coke Plants	20	50	80	90	90
VI. Biological Treatment	0	5	10	15	20
VII. Deep Well Disposal	0	2	5	10	15
VIII. Ion Exchange	0	2	5	10	20
IX. Neutralization & Sludge Lagooning	10	50	80	85	75
X. Regeneration Processes	0	0	2	5	10
XI. Proper Operation of Facilities	20	35	50	60	70

b. Plain sedimentation or coagulation and sedimentation, with or without recirculation, are substitutable techniques; efficiencies are not, of course, equal. In the case of cold mill effluents, the use of magnetic separators can be substituted for coagulation and sedimentation insofar as solids removal is concerned. Neutralization, regeneration, and deep well disposal are alternative techniques for the disposal of pickle liquor. Biological treatment and deep well disposal are alternative treatments for coke plant wastes. Quenching coke with still wastes or river water are alternative techniques which reduce wastes in coke plant or blast furnaces effluents respectively.

c. The waste treatment methods outlined are given as integral methods and have few interdependencies; interdependencies which affect costs and efficiencies are more to be found between alternative subprocesses than between waste treatment methods. The extent to which recirculation of process water is employed is the factor of most importance in this connection. Interdependencies between waste treatment processes are found in comparing relative air and water pollution abatement efficiencies, i.e., air pollution abatement measures very often result in potential water pollution problems and water pollution abatement measures sometimes result in air pollution problems.

3. a. Aside from the disposal of sanitary wastes generated by plant employees, very little of the industry's water are discharged to municipal sewers. Sanitary wastes amount to about 1% of the total wastes and possibly one-half of these wastes are discharged to municiapl sewers.

Pickle liquor may be discharged to municipal sewers, as may coke plant wastewaters. Such practices are very limited and do not exceed 5% of the industry's total wastewater disposal. The pickle liquor that is disposed of in this way is that from small installations. The percentage of such disposal practices employed in the industry is not likely to increase through 1977. In 1950 the percentage of such disposal was probably 2% or less.

Percentages of the industry's wastewaters discharged to municipal sewers may be estimated as follows:

1950	1963	1967	1972	1977
2%	3%	5%	5%	5%

Such discharges are generally from small installations. The practice is limited because sewage treatment plant operators fear the effects of these wastes on sewers and plant facilities, and

because of the political considerations inherent in the operation of many municipal systems. The technical feasibility of such discharges has often been demonstrated but seldom permitted for these reasons.

b. Acids can attack sewer materials and inhibit the biological processes in sewage treatment plants; sulfates can cause corrosion in concrete sewers of certain types. Coke plant wastes can inhibit sewage treatment processes due to the toxicity of phenols and cyanides.

Pickle liquor must be at least partially neutralized before discharge to municipal sewers and the flow rate must be regulated in relation to the relative volume of sewage to which it is added. Coke plant wastes must be added by controlled discharge so as not to upset the treatment plant processes; coke plant wastes can amount to as much as 5% of the combined flow to a sewage treatment plant.

C. By-Product Utilization

By-products are recovered and utilized from certain waste treatment processes in the industry. Such recovery is, however, inherent in the descriptions of the processes given above and does not further reduce wasteloads reaching watercourses. It is not likely that additional by-product utilization of this type will develop.

The suspended material from blast furnace gaswasher water and recovered mill scale are sintered and returned to the blast furnace or steelmaking furnace. Oils recovered from cold mill rolling solutions are processed for re-use in the mill operation or for sale. Acid regenerated from pickle liquor is returned to the pickling tanks.

Some other by-products are recovered in the course of gas-scrubbing cleaning operations which reduce potential wasteloads well ahead of the waste treatment processes described. Ammonium sulfate is produced in removing ammonia from coke oven gas with sulfuric acid; phenol is recovered from coke oven gas by vapor recirculation or solvent extraction. Copperas is produced from pickle liquor in a few plants and one or two plants are able to dispose of pickle liquor to chemical or pigment manufacturers.

D. Base Year Net Waste Quantities

Base year net wasteloads are given below for the broad categories of wastes previously described.

SUMMARY OF PROJECTED NET WASTELOADS (1972)

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	13,580 x 10^6	93.0	957 x 10^6
Lube Oil	306 x 10^6	28.8	211.9 x 10^6
Acids (1)	1,732.6 x 10^6	41.7	1,010.2 x 10^6
Soluble Metals	5.79 x 10^6	3.8	5.57 x 10^6
Emulsions	51.60 x 10^6	62.8	19.2 x 10^6
Coke Plant Chemicals	18.96 x 10^6	64.8	6.68 x 10^6
Fluorides	3.54 x 10^6	0	3.54 x 10^6

(1) Free and combined acids.

E. Projected Net Waste Quantities

Projected net waste quantities are given below for each of the years 1968-1972 and 1977 for the broad categories of wastes previously described.

SUMMARY OF PROJECTED NET WASTELOADS FOR 1968

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	18,350 x 10^6	93.5	1,187 x 10^6
Lube Oil	380 x 10^6	38.0	236.1 x 10^6
Acids (1)	2,193 x 10^6	72.0	614 x 10^6
Soluble Metals	7.75 x 10^6	12.0	6.84 x 10^6
Emulsions	79.10 x 10^6	71.6	23.8 x 10^6
Coke Plant Chemicals	24.05 x 10^6	91.5	2.12 x 10^6
Fluorides	4.37 x 10^6	0	4.37 x 10^6

(1) Free and combined acids.

SUMMARY OF PROJECTED NET WASTELOADS FOR 1969

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	19,146 x 10^6	93.7	1,205 x 10^6
Lube Oil	390.0 x 10^6	39.1	238 x 10^6
Acids (1)	2,189 x 10^6	74.1	566.8 x 10^6
Soluble Metals	8.11 x 10^6	13.7	7.00 x 10^6
Emulsions	83.9 x 10^6	72.0	23.5 x 10^6
Coke Plant Chemicals	24.82 x 10^6	91.5	2.11 x 10^6
Fluorides	4.51 x 10^6	0	4.51 x 10^6

(1) Free and combined acids.

SUMMARY OF PROJECTED NET WASTELOADS FOR 1970

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	20,080 x 10^6	93.9	1,223 x 10^6
Lube Oil	401 x 10^6	40.6	238.2 x 10^6
Acids (1)	2,335 x 10^6	76.2	554.7 x 10^6
Soluble Metals	8.46 x 10^6	15.5	7.14 x 10^6
Emulsions	90.5 x 10^6	72.3	25.2 x 10^6
Coke Plant Chemicals	25.62 x 10^6	91.5	2.18 x 10^6
Fluorides	4.65 x 10^6	0	4.65 x 10^6

(1) Free and combined acids

SUMMARY OF PROJECTED NET WASTELOADS FOR 1971

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	20,930 x 10^6	94.1	1,241 x 10^6
Lube Oil	412 x 10^6	42.0	238.8 x 10^6
Acids (1)	2,406 x 10^6	78.4	520.5 x 10^6
Soluble Metals	8.75 x 10^6	17.6	7.21 x 10^6
Emulsions	96.1 x 10^6	72.3	26.6 x 10^6
Coke Plant Chemicals	26.41 x 10^6	91.6	2.24 x 10^6
Fluorides	4.80 x 10^6	0	4.80 x 10^6

(1) Free and combined acids.

SUMMARY OF PROJECTED NET WASTELOADS FOR 1972

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	21,843 x 10^6	94.3	1,260 x 10^6
Lube Oil	424 x 10^6	43.5	239.6 x 10^6
Acids (1)	2,485 x 10^6	80.5	484.6 x 10^6
Soluble Metals	9.27 x 10^6	19.5	7.47 x 10^6
Emulsions	102 x 10^6	72.5	28.1 x 10^6
Coke Plant Chemicals	27.25 x 10^6	91.6	2.30 x 10^6
Fluorides	4.95 x 10^6	0	4.95 x 10^6

(1) Free and combined acids

SUMMARY OF PROJECTED NET WASTELOADS FOR 1977

Waste Component	Gross Waste Quantity Generated (lbs)	Percentage of Waste Reduction or Removal	Net Waste Quantity Discharged (lbs)
Suspended Solids	27,126 x 10^6	95.2	1,317 x 10^6
Lube Oil	486 x 10^6	52.0	233.2 x 10^6
Acids (1)	2,909 x 10^6	80.7	560.2 x 10^6
Soluble Metals	11.25 x 10^6	34.0	7.42 x 10^6
Emulsions	138 x 10^6	73.5	36.6 x 10^6
Coke Plant Chemicals	32 x 10^6	91.4	2.75 x 10^6
Fluorides	5.80 x 10^6	0	5.80 x 10^6

(1) Free and combined acids.

IV. WASTE REDUCTION OR REMOVAL COSTS

A. The replacement value of existing waste removal facilities and annual operating and maintenance expenditures by the industry for waste removal in 1966 are estimated from the following unit costs, which have been adjusted to 1966 price levels using the Engineering News Record Construction Cost Index.

CONSTRUCTION COST OF WASTE TREATMENT FACILITIES

Waste Treatment Method	Unit Basic	Unit Cost Low	Unit Cost Average	Unit Cost High
I Plain Sedimentation				
A Blast Furnace & Sinter Plant	Ingot ton/yr	$ 0.70	$ 1.25	$ 1.67
B Hot-Rolling Mills	Ingot ton/yr	1.11	1.67	2.50
II Coagulation and Sedimentation				
A Blast Furnace & Sinter Plant	Ingot ton/yr	$ 0.77	$ 1.38	$ 1.84
B Hot-Rolling Mills	Ingot ton/yr	1.22	1.84	2.75
C Cold Mills	Ingot ton/yr	1.50	2.00	3.00
III Recirculation and:				
A Plain Sedimentations:				
1. Blast Furnace & Sinter Plt.	Ingot ton/yr	$ 1.00	$ 1.50	$ 2.00
2. Hot-Rolling Mills	Ingot ton/yr	1.50	2.00	3.00
3. Cold Mills	Ingot ton/yr	1.50	2.00	3.00
B Coagulation & Sedimentation:				
1. Blast Furnace & Sinter Plt.	Ingot ton/yr	$ 1.20	$ 1.80	$ 2.40
2. Hot-Rolling Mills	Ingot ton/yr	1.80	2.40	3.60
3. Cold Mills	Ingot ton/yr	1.80	2.40	3.60
C Magnetic Separators	1000 gals/min	$10,000	$20,000	$30,000
IV River Water for Coke Quenching				
A Blast Furnace	-	-	-	-
V Still Waste for Coke Quenching				
A Coke Plants	-	-	-	-
VI Biological Treatment	Ingot ton/yr	$ 0.14	$ 0.20	$ 0.35
VII Deep Well Disposal	Plant	$200,000	$500,000	$1,000,000
VIII Ion Exchange	50,000 gal/day	-	$100,000	-
IX Neutralization & Sludge Lagooning	100,000 gal/day	-	$1,000,000	-
X Regeneration of Pickle Liquor	100,000 gal/day	-	$4,000,000	-
XI Proper Operation of Facilities	-	-	-	-

Based upon the average size plant, the estimated percentages of plants utilizing particular treatment processes, and steelmaking capacity of about 160 million ingot tons per year, the following totals are estimated for 1966:

Waste Treatment Method	%Used	Unit Cost	Unit	Total Cost
I Plain Sedimentation				
A Blast Furnace & Sinter Plant	80	$ 1.25	Ingot Ton/yr	$160,000,000
B Hot-Rolling Mills	68	1.67	Ingot Ton/yr	$181,300,000
II Coagulation & Sedimentation				
A Blast Furnace & Sinter Plant	5	$ 1.38	Ingot Ton/yr	$ 11,000,000
B Hot-Rolling Mills	2	$ 1.84	Ingot Ton/yr	5,890,000
C Cold Mills	4	2.00	Ingot Ton/yr	12,800,000
III Recirculation and:				
A Plain Sedimentation				
1. Blast Furnace & Sinter Plant	10	$ 1.50	Ingot Ton/yr	$ 24,000,000
2. Hot-Rolling Mills	20	$ 2.00	Ingot Ton/yr	64,000,000
3. Cold Mills	70	$ 2.00	Ingot Ton/yr	$224,000,000
B Coagulation & Sedimentation				
1. Blast Furnace & Sinter Plant	5	$ 1.80	Ingot Ton/yr	$ 14,400,000
2. Hot-Rolling Mills	10	$ 2.40	Ingot Ton/yr	38,400,000
3. Cold Mills	20	$ 2.40	Ingot Ton/yr	76,800,000
C Magnetic Separators	15	$20,000	1000 gpm	353,000
IV Biological Treatment	10	$ 0.20	Ingot Ton/yr	$ 3,200,000
V Deep Well Disposal	5	$200,000	Plant	$ 2,370,000
VI Ion Exchange	5	$100,000	50,000 gpd	$ 1,600,000
VII Neutralization & Lagooning	80	$1,300,000	100,000 gpd	$ 42,200,000
VIII Regeneration Processes	2	$4,000,000	100,000 gpd	$ 3,250,000
			Total	$865,563,000

In the 8 years from 1955 to 1963 steel capacity increased from 125 to 155 million tons per year; during this period the industry invested about 1.42 billion dollars per year in plant and equipment on the average in terms of 1965 dollars. The replacement value of plant

and equipment in current dollars on the basis of these figures would be about $60 billion dollars. An average replacement value of $387 per annual ingot ton of capacity is indicated by these figures. The value of older equipment producing heavier unit products is about 2/3 of this average value, while that of newer equipment producing lighter unit products is about 1/3 greater.

The estimated replacement value of waste treatment facilities of $865 million dollars represents about 1.44% of total investment in plant and equipment in 1966. This percentage agrees well with estimates previously given in the technical literature by others.

Operating costs for various treatment processes are given in Table XIII. Direct costs include labor, supervision, maintenance and supplies; indirect costs include amortization, general overhead, taxes, and insurance.

Based upon the average size plant, the estimated percentages of plants utilizing particular treatment processes, steelmaking production of 135 million ingot tons annually, and the wastewater volumes previously given, the annual expenditures are estimated for the year 1966 in Table XIV.

B. 1. a. Subprocess Costs

Capital costs and annual operating and maintenance expenditures are estimated for the three levels of technology and plant sizes for subprocess and for the corresponding treatment methods. The estimates of costs and expenditures associated with processing are order-of-magnitude figures; this type of data is not readily available and is, in fact, quite closely held within the industry. The capital costs given are based upon the following unit estimates.

Subprocess	Capital Cost, $/Ingot Ton		
	Old	Typical	New
Electric Furnace	$25	$ 20	$ 15
Basic Oxygen Process	----	----	$ 20
Open-Hearth Furnaces	$50	$ 40	----
Primary Mills	----	$ 50	----
Finishing Mills	$80	$100	$120
Cold Mills	$85	$ 90	$100
Blast Furnaces	----	$ 35	----
Coke Ovens	----	$ 35	----
Finishing Operations	----	$ 50	$ 60
Cleaning Operations	----	$ 40	$ 50
Continuous Casting	----	----	$ 16

TABLE VIII

OPERATING COSTS FOR WASTE TREATMENT PROCESSES

Treatment Process	Net Cost per 1000 gal.	% Distribution of Costs			Cost per 1000 gal.		Credit per 1000 gal.
		Direct	Indirect	Credits	Direct	Indirect	
Blast Furnace & Sinter Plant							
Plain Sedimentation	$ 0.145	95.2	58.1	53.4	$ 0.138	$ .084	$ 0.077
Coagulation & Sedimentation	$ 0.368	80.0	46.1	26.1	$ 0.294	$ .123	$ 0.071
Hot Rolling Mills							
Plain Sedimentation	($ 0.043)	-	-	-	$ 0.023	$0.014	$ 0.030
Coagulation & Sedimentation	$ 0.072	169	69.7	139	$ 0.122	$0.050	$ 0.100
Coke Plant							
Biological Treatment	$0.151	64.2	35.8	0	$ 0.097	$0.054	-
Pickling Waste							
Neutralization	$20.00	92.8	7.2	0	$18.56	$1.44	-
Incineration	$ 8.30	266	84.7	251	$22.09	$7.45	$22.05
Deep Well Disposal	$ 1.00	68.0	32.0	0	$ 0.68	$0.32	0
Ion Exchange	$ 2.52	71.4	28.6	0	$ 1.80	$0.72	0
Miscellaneous	$1.00/ingot ton	27.0	73.0	0	$ 0.034	$0.091	0

TABLE XI

WASTEWATER TREATMENT EXPENDITURES 1966

Waste Treatment Method	% Used	1000 gal. per ton	10^6 gal. Treated/yr.	$/1000 gal. Direct	Indirect	Credit
I. Plain Sedimentation						
A. Blast Furnace and Sinter Plant	80	2.25	243,000	$0.138	$0.084	$0.077
B. Hot-Rolling Mills	68	4.21	386,000	$0.023	$0.014	$0.000
II. Coagulation and Sedimentation						
A. Blast Furnace and Sinter Plant	5	2.25	15,200	$0.214	$0.123	$0.071
B. Hot-Rolling Mills	2	4.21	11,400	$0.122	$0.050	$0.100
C. Cold Mills	4	0.334	1,800	$0.122	$0.055	$0.010
III. Recirculation and:						
A. Plain Sedimentation:						
1. Blast Furnace and Sinter Plant	10	2.25	30,400	$0.138	$0.101	-
2. Hot-Rolling Mills	20	4.21	113,500	$0.023	$0.017	-
3. Cold Mills	70	0.334	31,600	$0.023	$0.017	$0.010
B. Coagulation and Sedimentation						
1. Blast Furnace and Sinter Plant	5	2.25	15,200	$0.214	$0.121	-
2. Hot-Rolling Mills	10	4.21	56,750	$0.122	$0.204	-
3. Cold Mills	20	0.334	9,020	$0.122	$0.034	$0.010
C. Magnetic Separators	15	0.334	6,770	$0.034	$0.001	-

TABLE XIV

Wastewater Treatment Expenditures 1966 (Continued)

Waste Treatment Method	% Used	1000 gal. per ton	10^6 gal. Treated/yr.	$/1000 gal. Direct	Indirect	Credit
IV. Biological Treatment	10	3.04	41,100	$ 0.097	$0.054	-
V. Deep Well Disposal	5	0.00932	63.0	$ 0.68	$0.32	-
VI. Ion Exchange	5	0.035	236	$ 1.80	$0.72	-
VII. Neutralization and Lagooning	80	0.00932	1010	$18.56	$1.44	- -
VIII. Regeneration Processes	2	0.00932	25.2	$23.40	$7.45	$22.05
Annual Totals @ 135 million ingot tons				$90,104,240	$53,815,670	$53,601,860

Operating labor costs are approximately 54% of the value added by manufacture in the industry, which was about $78.50 per ingot ton in 1966. Materials, supplies, freight and other services amounted to about $60.50 per ingot ton. Direct operating and maintenance expenses thus amounted to $102.90 per ingot ton in 1966. Allotting these expenses in proportion to capital costs yields the following estimates of operating and maintenance expenses per subprocess.

Subprocess	Operating & Maintenance Expense, $/Ingot Ton		
	Old	Typical	New
Electric Furnace	---	$ 3.99	---
Basic Oxygen Process	---	---	$ 5.32
Open-Hearth Furnace	---	$10.63	---
Primary Mills	---	$13.30	---
Finishing Mills	$21.30	$26.60	$31.90
Cold Mills	$22.60	$23.90	$26.60
Blast Furnace	---	$ 9.30	---
Coke Ovens	---	$ 9.30	---
Finishing Operations	---	$13.30	$15.95
Cleaning Operations	---	$10.63	$13.30
Continuous Casting	---	---	$ 4.25

b. The estimates given here include credits taken for modified technology and by-product recovery. Costs would be higher if by-products were not recovered and the increased costs can be estimated from the figures given previously. By-product recovery is limited in the steel industry, however, and by-products such as the flue dust and mill scale are always recovered.

c. The estimates given here for waste treatment methods are industry averages. Costs for installation in new plants may be taken as 70% of the average. The average costs given apply to installations in existing plants when adequate space is easily available for treatment facilities. Costs in smaller existing plants, which are particularly crowded and require equipment relocations, may be taken as 135% of the averages given.

2. In 1964 companies representing 95% of the industry's capacity had invested $21,493,835,013 in plant and equipment; depreciation and amortization had reduced net fixed assets to $9,304,780,908. Capacity in 1964 was estimated to have been 157 million ingot tons. Depreciation and amortization from 1964 to 1965 amounted to $852,296,645 on an average asset value of $22,295,359,330; i.e., 3.84%. The average economic life of plant and equipment is thus about 26 years in the industry. The economic life of treatment facilities tends to be from 15-20 years on the average, but varies widely depending upon the specific facility involved.

3. In Tables XV, XVI and XVII, capital costs and annual operating and maintenance costs are estimated for the [illegible] of waste treatment methods employed in 1966 by plants of various sizes operating at the various levels of technology. These estimates are based upon the following assumptions:

The unit costs of waste treatment facilities in other plants is maximum, the unit costs for new plants are minimum.

Old Technology

The small plant is assumed to have electric furnaces with no air pollution control and to have blooming mill and billet and rod mills, with plain sedimentation in conventional scale pits.

The average plant is assumed to have blast furnaces utilizing plain sedimentation to treat gas-cooler water; open-hearth furnaces with no air pollution control; hot-rolling mills utilizing plain sedimentation to treat mill scale suspensions; pickling with waste treatment by neutralization, cold mills operated with recirculation and plain sedimentation; tinplating and galvanizing with no waste treatment; and a coke plant operating with no waste treatment, other than coke quenching.

The large plant is assumed to be similar to the average plant.

Typical Technology

The small plant is assumed to be similar to that of the old technology, but with cold-finishing mills operated on the basis of recirculation and plain sedimentation of coolant solutions.

The average plant is assumed to be similar to that of the old technology, but with recirculation and plain sedimentation of hot-mill effluents.

The large plant is assumed to be similar to the average plant.

Advanced Technology

The small plant is assumed to be similar to that of the typical technology, but with recirculation and plain sedimentation of hot-mill effluents.

The average plant is assumed to be similar to that of typical technology, but with coagulation and sedimentation of blast furnace gas-cooler water, recirculation, coagulation and sedimentation of hot-mill effluents, deep well disposal of pickling solutions, and to

have oxygen-lanced open-hearths and/or basic oxygen furnaces equipped with water scrubbers, the effluents of which are treated by recirculation and plain sedimentation.

The large plant is assumed to be similar to the average plant.

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TABLE XV

COSTS OF SUBPROCESSES AND TREATMENT ACTIONS (1966) - OLD TECHNOLOGY

	Capital Cost ($)	Annual Costs ($)	Economic Life (Yrs)
Small Plant - 200 000 Ingot Tons Annually			
Electric Furnaces	$ 5,000,000	$ 798,000	20
Hot-Rolling Mills	26,000,000	6,920,000	25
Plain Sedimentation (1b)	500,000	$ 17,000	50
Average Plant - 700,000 Ingot Tons Annually			
Blast Furnaces	$ 24,500,000	$ 6,510,000	30
Open-Hearth Furnaces	35,000,000	7,441,000	30
Hot-Rolling Mills	91,000,000	24,220,000	25
Cleaning	28,000,000	7,441,000	20
Cold Mills	59,500,000	15,820,000	20
Finishing	35,000,000	9,310,000	15
Coke Plant	24,500,000	6,510,000	20
Plain Sedimentation (1A)	$ 1,169,000	$ 251,300	20
Plain Sedimentation (1B)	1,750,000	59,500	50
Acid Neutralization (IX)	858,000	338,700	10
Recirculation and Sed. (IIIA3)	2,100,000	4,300	20
Large Plant - 1,200,000 Ingot Tons Annually			
Blast Furnaces	$ 42,000,000	$ 11,160,000	30
Open-Hearth Furnaces	60,000,000	12,756,000	30
Hot-Rolling Mills	156,000,000	41,520,000	25
Cleaning	48,000,000	12,756,000	20
Cold Mills	102,000,000	27,120,000	20
Finishing	60,000,000	15,960,000	15
Coke Plant	42,000,000	11,160,000	20
Plain Sedimentation (1A)	$ 2,004,000	$ 430,800	20
Plain Sedimentation (1B)	3,000,000	102,000	50
Acid Neutralization (IX)	1,185,000	580,600	10
Recirculation and Sed. (IIIA3)	3,600,000	7,400	20

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COSTS OF SUBPROCESSES AND [illegible] METHODS (1966) [illegible] TECHNOLOGY

	Capital Cost ($)	Annual Cost ($)	Economic Life (Yrs)
Small Plant - 700,000 Ingot Tons Annually			
Electric Furnaces	$ 14,000,000	$ 2,793,000	20
Hot-Rolling Mills	105,000,000	27,930,000	25
Cold Mills	63,000,000	16,730,000	20
Plain Sedimentation (IB)	$ 1,169,000	$ 67,600	50
Recirculation and Sed. (III A3)	1,400,000	4,300	20
Average Plant - 1,500,000 Ingot Tons Annually			
Blast Furnaces	$ 52,500,000	$ 13,950,000	30
Open Hearth Furnaces	60,000,000	15,945,000	30
Hot-Rolling Mills	225,000,000	59,850,000	25
Cleaning	60,000,000	15,945,000	20
Cold Mills	135,000,000	35,850,000	20
Finishing	75,000,000	19,950,000	15
Coke Plant	52,500,000	13,950,000	20
Plain Sedimentation (IA)	$ 1,875,000	$ 415,600	20
Recirculation and Sed. (III A2)	3,000,000	145,200	20
Acid Neutralization (IX)	1,495,000	853,600	10
Recirculation and Sed. (III A3)	3,000,000	11,500	20
Large Plant - 3,000,000 Ingot Tons Annually			
Blast Furnaces	$105,000,000	$ 27,900,000	30
Open-Hearth Furnaces	120,000,000	31,890,000	30
Hot-Rolling Mills	450,000,000	119,700,000	25
Cleaning	120,000,000	31,890,000	20
Cold Mills	270,000,000	71,700,000	20
Finishing	150,000,000	39,900,000	15
Coke Plant	105,000,000	27,900,000	20
Plain Sedimentation (IA)	$ 3,750,000	$ 831,200	20
Recirculation and Sed. (III A2)	6,000,000	290,400	20
Acid Neutralization (IX)	2,266,000	1,707,200	10
Recirculation and Sed. (III A3)	6,000,000	23,000	20

TABLE XVII

COSTS OF SUBCATEGORIES AND TREATMENT METHODS (1976) ADVANCED TECHNOLOGY

	Capital Cost ($)	Annual Cost ($)	Economic Life (Yrs)
Small Plant - 1,000,000 Ingot Tons Annually			
Electric Furnaces	$ 15,000,000	$ 3,990,000	20
Hot-Rolling Mills	170,000,000	45,200,000	25
Cold Mills	100,000,000	26,600,000	20
Recirculation and Sed. (IIIA2)	$ 1,500,000	$ 131,000	20
Recirculation and Sed. (IIIA3)	1,500,000	21,000	20
Average Plant - 3,000,000 Ingot Tons Annually			
Blast Furnaces	$105,000,000	$ 27,900,000	30
Open-Hearth Furnaces	40,000,000	10,630,000	30
Basic Oxygen Furnaces	40,000,000	10,640,000	20
Hot Rolling Mills	510,000,000	135,600,000	25
Cleaning	150,000,000	39,000,000	20
Cold Mills	300,000,000	79,800,000	20
Finishing	180,000,000	47,850,000	15
Coke Plant	105,000,000	27,900,000	20
Coagulation and Sed. (IIA)	$ 2,310,000	$ 1,616,900	20
Recir., Coag., and Sed. (IIIB2)	5,400,000	2,081,200	25
Deep Well Disposal (VII)	500,000	60,100	15
Recirculation and Sed. (IIIA1)	3,000,000	580,800	20
Recirculation and Sed. (IIIA3)	4,500,000	64,700	20
Large Plant - 5,000,000 Ingot Tons Annually			
Blast Furnaces	$175,000,000	$ 46,500,000	30
Open-Hearth Furnaces	80,000,000	21,260,000	30
Basic Oxygen Furnaces	60,000,000	15,960,000	20
Hot-Rolling Mills	850,000,000	226,000,000	25
Cleaning	250,000,000	66,500,000	20
Cold Mills	500,000,000	133,000,000	20
Finishing	300,000,000	70,750,000	15
Coke Plant	175,000,000	46,500,000	20
Coagulation and Sed. (IIA)	$ 3,850,000	$ 2,700,000	20
Recir., Coag., and Sed. (IIIB2)	9,000,000	3,480,000	25
Deep Well Disposal (VII)	1,000,000	100,000	15
Recirculation and Sed. (IIIA1)	5,000,000	970,000	20
Recirculation and Sed. (IIIA3)	7,500,000	100,000	20

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