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The Use and Fate of Lubricants, Oils, Greases, and Hydraulic Fluids in the Iron and Steel Industry

Pacific Environmental Services, Inc, Santa Monica, Calif

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1-A

ABSTRACT

This report presents the results of an investigation of the use and fate of lubricants, oils, greases and hydraulic fluids in the iron and steel industry. Data from nine integrated steel plants and two consultants with extensive steel industry experience were used to: (1) develop correlations between lubricant usage rates and steel production capacity and the types of products made; and (2) prepare total oil, grease and hydraulic fluid material balances for specific, as well as, a "typical" integrated steel plant. Generalizations were made regarding the fate (as air pollution, water pollution and solid waste) of these oils, greases and hydraulic fluids. Estimates of the mass air pollution emissions, the total oil and grease water pollution discharges, and the quantity of oil and grease being disposed of in landfills were developed by steel-making area and for a typical integrated steel plant. Introductory and background information pertaining to the steel industry, lubrication practices, steel plant lubricants, and waste oil collection and reclamation methods are also presented.

Results of the study indicate that for a typical integrated steel plant, with a raw steel production capacity of 3.6 x 10^9 kg/yr (4 x 10^6 tons/yr), 544,000 kg/mo (1,200,000 lb/mo) of oils, greases and hydraulic fluids are used throughout the plant. Approximately 90% of these lubricants are used in the steel rolling and finishing operations. It was estimated that of the total quantity of oil, grease and hydraulic fluid used at a typical plant approximately 10% enters the environment as air pollution, 9% as water pollution and 44% as solid waste.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

CONVERSION FACTORS

Much of the data collected during the performance of this study were reported in English units. Where possible System International (SI) units of measure were used in the text of this report. When deemed impractical to convert data tables to SI units a conversion factor is indicated. Following are the factors for conversion between English and SI units of measure.

1 lb (pound)	=	0.4536 kg (kilogram)
1 ton (short ton)	=	0.9072 metric ton (907.2 kg)
1 ft (foot)	=	0.3048 m (meter)
1 in (inch)	=	2.54 cm (centimeters)
1 gal (gallon)	=	3.7853 l (liter) or m^3 (cubic meter)
1 MGD (million gallons per day)	=	0.0438 m^3/s (cubic meters per second)
1 GPM (gallon per minute)	=	6.309 x 10^{-5} m^3/s (cubic meters per second)
1 psi (pound per square inch)	=	6895 Pa (Pascal)
1 lb/ton	=	0.5 kg/1000 kg
1 gal/ton	=	4.172 l/1000 kg

°F = 1.8°C + 32

I. INTRODUCTION

Steel is the most widely used single industrial material for the manufacture of transportation equipment, construction materials, durable goods, defense hardware and metal containers. The iron and steel industry is the largest single industry in the United States and, American steel producers, with an annual production capacity of approximately 136 million metric tons (150 million tons), consistently rank first or second among world producers. The 1975 production level was about 76 percent of the annual production capacity and represented about 16 percent of the total world steel production.[1]

There are over 200 steel producing plants in the U.S. but only about fifty of these are integrated from the blast furnace through the rolling mills. In 1975, approximately 90 percent of the total U.S. annual steel ingot production was produced by fifteen major steel corporations. Figures 1-1 and 1-2 present the plant locations of all integrated steel plants in the United States. Table 1-1 lists all integrated steel plants in the United States and provides production capacity data.[2] Only integrated steel companies were surveyed and investigated in this project, and consequently, the applicability of the project findings to non-integrated and specialty steel companies is unknown. Non-integrated and specialty steel companies account for a small fraction (about one-seventh) of the total American raw steel capacity.

The usage of lubricants, oils, greases and hydraulic fluids in the iron and steel industry is generally recognized as a potentially significant source of pollution due to the large quantities that are used and the numerous applications of these materials in a typical steel mill. Pacific Environmental Services was contracted by the Environmental Protection Agency's Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina, to

Note: Plant names and capacities are listed in Table 1-1.

Figure 1-1. INTEGRATED STEEL PLANT LOCATIONS

Figure 1-2. INTEGRATED STEEL PLANT LOCATIONS

Table 1-1. USA-INTEGRATED STEEL COMPANIES AND PLANT CAPACITIES

Company And Plant Location		Raw Steel Capacity Net Tons
1. ALAN WOOD STEEL COMPANY		
Conshohocken	Pennsylvania	1,500,000
2. ARMCO STEEL CORPORATION		
a. Ashland	Kentucky	2,000,000
b. Houston	Texas	1,500,000
c. Middletown	Ohio	3,800,000
3. BETHLEHEM STEEL CORPORATION		
a. Bethlehem	Pennsylvania	3,600,000
b. Burns Harbor	Indiana	4,500,000
c. Johnstown	Pennsylvania	2,400,000
d. Lackawanna	New York	6,000,000
e. Sparrows Point	Maryland	7,500,000
4. C F & I STEEL CORPORATION		
Pueblo	Colorado	1,665,000
5. CRUCIBLE, INCORPORATED		
Alloy Division		
Midland	Pennsylvania	1,000,000
6. CYCLOPS CORPORATION		
Portsmouth	Ohio	1,000,000
7. FORD MOTOR COMPANY		
Dearborn	Michigan	3,750,000
8. INLAND STEEL COMPANY		
East Chicago	Indiana	8,200,000
9. INTERLAKE, INCORPORATED		
Chicago	Illinois	900,000
10. INTERNATIONAL HARVESTER COMPANY		
South Chicago	Illinois	1,200,000
11. JONES AND LAUGHLIN STEEL CORPORATION		
a. Aliquippa	Pennsylvania	3,840,000
b. Cleveland	Ohio	3,100,000
c. Pittsburgh	Pennsylvania	1,800,000
12. KAISER STEEL CORPORATION		
Fontana	California	4,000,000
13. LONE STAR STEEL COMPANY		
Lone Star	Texas	1,500,000
14. McLOUTH STEEL CORPORATION		
Trenton	Michigan	3,400,000
15. NATIONAL STEEL CORPORATION		
a. Granite City	Illinois	2,500,000
b. Ecorse	Michigan	6,600,000
c. Weirton	West Virginia	4,000,000
16. REPUBLIC STEEL CORPORATION		
a. Buffalo	New York	1,000,000
b. Canton (Massilon)	Ohio	1,500,000
c. Cleveland	Ohio	4,400,000
d. Gadsden	Alabama	1,500,000
e. South Chicago	Illinois	2,000,000
f. Warren (Youngstown)	Ohio	2,700,000
17. SHARON STEEL CORPORATION		
Farrell	Pennsylvania	1,900,000
18. UNITED STATES STEEL CORPORATION		
a. Braddock	Pennsylvania	2,500,000
b. Duquesne	Pennsylvania	3,000,000
c. Fairfield	Alabama	3,500,000
d. Fairless Hills	Pennsylvania	4,400,000
e. Gary	Indiana	8,000,000
f. Geneva	Utah	2,750,000
g. Homestead	Pennsylvania	[illegible],000,000
h. Lorain	Ohio	3,000,000
i. South Chicago	Illinois	5,250,000
j. Youngstown	Ohio	2,500,000
19. WHEELING-PITTSBURGH STEEL CORPORATION		
a. Monessen	Pennsylvania	1,600,000
b. Steubenville	Ohio	2,800,000
20. YOUNGSTOWN SHEET AND TUBE COMPANY		
a. East Chicago	Indiana	5,500,000
b. Brier Hill (Youngstown)	Ohio	1,500,000
c. Youngstown	Ohio	2,000,000
TOTAL		148,555,000

See Figures 1-1 and 1-2 for locations

Note: 1 Ton = 907.2 kg

investigate the use and fate of all lubricants, oils, greases and hydraulic fluids in the iron and steel industry. Fuel oils, solvents, tars, pitch, transformer oils, wash oils and quench oils were excluded from the investigation. The objectives of the program included the determination of (1) the types of lubricants and hydraulic fluids utilized and their application, (2) the formation and deposition of air and water contaminants formed by the use of these lubricants in the various steel production and processing operations, and (3) current waste oil and grease control, collection, and reclamation practices. A very ambitious study program was initiated to accomplish the study objectives via literature search and review, questionnaires, visits to typical large integrated steel plants, and engineering analyses of all available data.

The initial project task was a comprehensive literature search utilizing the resources of several technical libraries, trade journals, texts, handbooks, technical papers and NTIS microfiche. Background information was collected on processes and equipment, lubrication practices and usage, and waste oil collection and reclamation. Organizations, societies and institutes supported by, knowledgeable of, or composed of iron and steel personnel were contacted to obtain information useful for the PES study.

The second major task was to obtain detailed and current data on steel mill lubrication and waste oil collection and reclamation from representative integrated iron and steel mills in the United States. This task involved several contacts and visits to EPA and state pollution control agencies to obtain pertinent data from NPDES and other files. In addition, manufacturers and distributors of oils, greases and hydraulic fluids were contacted and literature and specifications of lubricants were obtained. This second project task was the most time consuming and perhaps the most important. To obtain data from the steel industry, PES developed an "Iron and Steel Mill Lubrication Questionnaire" and sent it to nine representative integrated mills. Several months of effort and numerous telephone calls and correspondence with steel mills was required to secure adequate responses from the industry. Visits were arranged to discuss the project objectives, review information and data solicited in the questionnaire, and to obtain additional information via interviews and facility inspection. Six of the nine steel plants surveyed allowed PES to visit their facilities. Although information was received from all nine mills, information and data sufficient to develop oil, grease and hydraulic material balance estimates were gathered for only seven of the surveyed steel mills.

Two consultants with considerable experience in the steel industry were utilized to provide technical support throughout the project. To supplement the data from the steel mills, PES contacted waste oil reclaimers that handled waste oils from one or more of the nine mills being surveyed and requested them to provide relevant information and data.

The information and data acquired from the literature, steel industry questionnaires and visits, pollution control agencies waste oil reclaimers, and the consultants were analyzed and used to develop the material balances and typical values for oil, grease, and hydraulic fluid usage, as well as conclusions regarding the fates of these materials at integrated steel mills.

The following report presents the findings and describes the analyses performed. Sections 2 through 6 provide a general description of (1) the iron and steel processes and equipment used for making and shaping steel; (2) lubrication systems and practices; (3) types and properties of oils, greases and hydraulic fluids; (4) waste oil collection, reclamation and disposal methods; and (5) wastewater sampling and analysis procedures for oil and grease. Sections 7 and 8 present a detailed description of the methodology used for gathering information, and data obtained from the nine steel mills surveyed and the data analyses performed. Section 9 summarizes the project findings and provides generalization which can be drawn from the data. The project conclusions and areas or problems requiring further study are identified in Section 10. The report also includes a list of references that were used during the course of this project, and appendices, which provide other data that were used in the PES study.

Throughout the report, as in the steel industry, the terms steel mill and steel plant are used interchangeably. In actuality, a steel plant is generally composed of steelmaking equipment and mills for rolling and shaping the steel. Commonly, the term steel mill is used to refer to the entire steel plant, not just the rolling mills.

2. PROCESS AND EQUIPMENT DESCRIPTION

A general knowledge of the processes and equipment utilized in the making and shaping of iron and steel is needed to understand and appreciate the quantities and varieties of oils, greases and hydraulic fluids purchased by the steel industry. This chapter gives a brief general description of iron and steel making, the shaping processes involved, and the equipment used. The equipment that utilizes lubricants, oils, greases, or hydraulic fluids is also identified.

2.1 General Iron and Steel Making and Shaping

The making and shaping of iron and steel is outlined below. A more detailed description of these processes and equipment is presented in The Making, Shaping and Treating of Steel, available from United States Steel Corporation.[3] A simplified flow chart of steel making is illustrated in Figure 2-1.

2.1.1 Raw Materials

Several basic materials are involved in the production of pig iron in the blast furnace. These are iron ore, sinter, pellets, mill scale, scrap metal, coke, limestone and sometimes dolomite.

Iron ore is of varying chemical formulae and metal content. It consists chiefly of oxides such as Fe_2O_3 or Fe_3O_4, and some carbonate $FeCO_3$. Small amounts of silica, aluminum, calcium, magnesium, phosphorous and other contaminants are also present.

Upon arriving at the mill, the ore is removed from boats or cars by an unloader and transferred to the ore storage yard by ore bridges. From the yard the ore is moved by transfer cars to the stockhouses at the base of the blast furnace.

Courtesy of American Iron and Steel Institute

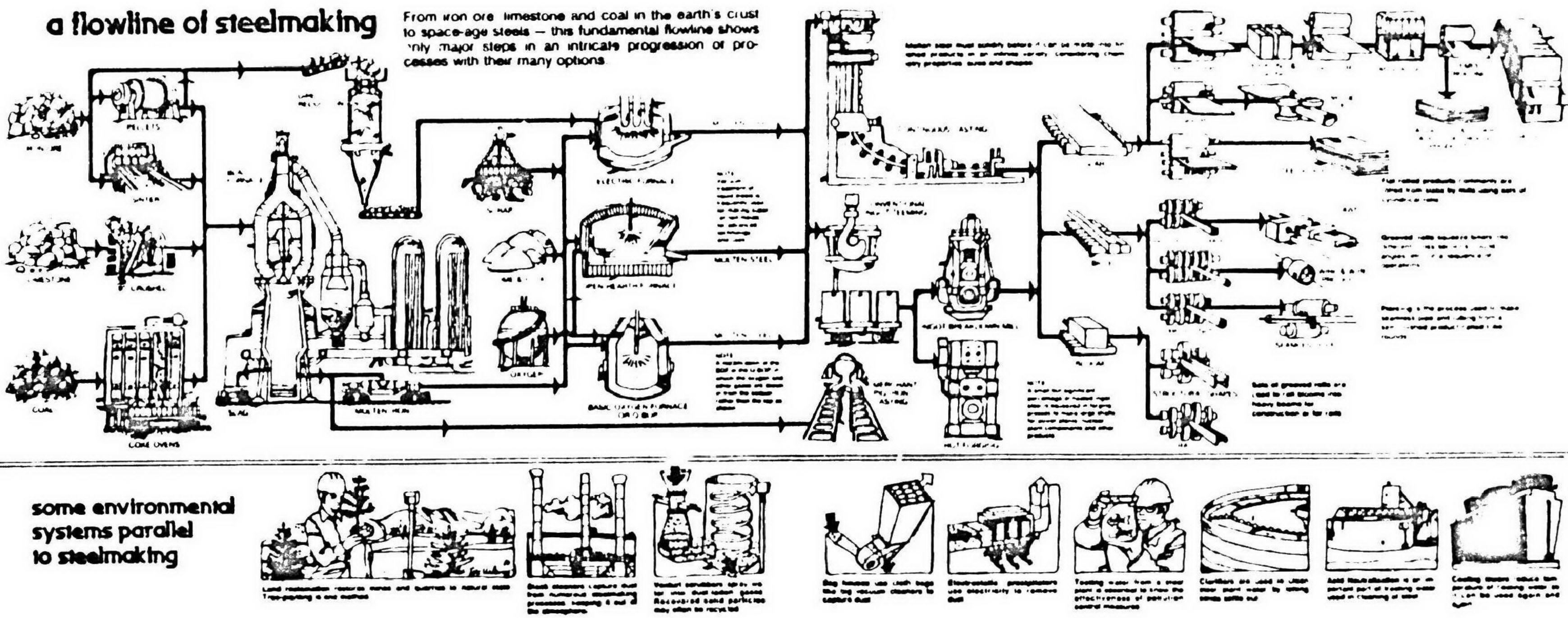


Figure 2-1 FLOW CHART OF STEELMAKING

Sintering is one of the methods used to improve or enrich the blast furnace charge. Ore, as received, may contain considerable quantities of fines which may create problems in the blast furnace and can easily become "lost" in handling and processing operations. To recover the fines and utilize other metal bearing wastes, sintering plants are employed. In these plants the following materials are blended together:

1. Ore fines;
2. Flue dust from blast furnace, basic oxygen furnaces and other plant operations;
3. Exhaust dust from sintering and air pollution control units;
4. Mill scales from rolling operation scale pits;
5. Limestone fines;
6. Coke breeze and sometimes powdered coal.

This mixture can be fed directly into the sinter machine or may be formed with water into small balls or briquets and then charged to the machine. The mixture is ignited on a traveling grate causing it to fuse into porous, coherent lumps. The sinter is cooled, broken into pieces of a desired size, and fed into the blast furnace. Pellets are also used along with sinter. Pellets are made from beneficiated ore that is mixed with a binder, formed in a balling drum and then fired so that they have sufficient strength for handling.

Limestone functions in the production of iron as a flux for sequestering impurities in the ore and coke charged to the blast furnace. From storage piles in an area adjacent to the iron ore, it is moved to the stockhouses at the base of the blast furnace and is charged into the furnace in the same manner as ore or coke.

Metallurgical coke, which acts as the source of heat in the blast furnace and also as the reducing agent for the iron oxides, is manufactured by destructive distillation of crushed bituminous coal in specially designed high and narrow coke ovens. Coal is charged into the top of the ovens by larry cars. It is then heated to approximately 1100°C (2000°F) for about 15 to 18 hours. White-hot coke is then "pushed" through a coke guide into quench cars. The cars transport the coke to a quenching station where it is rapidly cooled with water to prevent further burning. After quenching, the coke is dumped in a storage area. Gases which leave the coke ovens are cooled by spraying with flushing liquor. Ammonia, light oils, and coal tars are removed from the liquor before the stripped gas is sent to the plant fuel gas system.

2.1.2 Pig Iron Manufacture

The basic raw materials (iron ore, pellets, sinter, mill scale. scrap, limestone, and coke) are processed in the blast furnace to produce an iron with a high carbon content -- pig iron.

The charge is added to the top of the furnace by a skip hoist or conveyor belt. The skip cars are filled from stockhouses at the base of the unit. The charging is done in alternate layers of ore, coke and limestone to promote even melting. To provide the needed heat, air to react with the coke is forced by blowers through the tuyeres arranged around the base of the furnace. The carbon monoxide from the coke, at the high temperatures, reduces the ore to metallic iron which runs to the furnace bottom. The limestore converts to lime and combines with other elements to accumulate as slag floating on the heavier iron. The slag is withdrawn from the furnace through the cinder notch and slag runners into the ladle cars. Molten iron or hot metal is then "cast" from the furnace through the tap hole into hot metal cars. Blast furnace gas after cleaning is later used as fuel at the furnace stoves or other points in the plant.

Once the blast furnace has been tapped the molten iron must be removed. It may be discharged directly into a pig casting machine and formed into solid bars or pigs, or it may be placed in a hot metal car or ladle. The hot metal car or ladle delivers the molten iron to a mixer or to steel furnaces. In some instances molten metal is delivered to nearby foundaries for direct use.

The metal mixer serves two main purposes:

1. It keeps the metal molten until ready for further processing, and
2. It allows mixing of metal from various blast furnace batches to provide a larger uniform batch.

2.1.3 Manufacture of Steel

In its simplest form, steel is iron refined to contain less than two percent carbon. The two most dominant methods in use today are the basic oxygen and electric arc processes; the open hearth method is still being used, but it is rapidly being displaced. The amount of raw steel produced by open hearth furnaces in the United States has decreased from 84 percent in 1962 to 19 percent in 1975. The basic oxygen furnace converts molten pig iron and scrap to steel by blowing large quantities of oxygen into the charge to react with the carbon and other impurities. This process has a higher production rate than open hearth furnaces. In the United States, basic oxygen furnace production has increased from 7 percent of the raw steel produced in 1962 to 62 percent in 1975. Electric furnaces are generally charged with cold scrap and alloying agents to produce a variety of steels. Heat is produced by electricity flowing through the metal. Domestic steel production by electric furnaces has increased from 9 percent in 1962 to 19 percent in 1975.

2.1.3.1 Basic Oxygen Process. The basic oxygen process is closely related to the old Bessemer method. The substitution of oxygen for air is the essential difference. A refractory-lined, pear-shaped vessel is used which can be tilted to either side for tapping and charging. Scrap and molten metal constitute the charge, with metal making up about 70 percent of the mass.

The furnace is tilted before it is charged after which it is returned to an upright position, and a water-cooled oxygen lance is lowered into the vessel. Oxygen is injected under pressure and high velocity and a reaction occurs with the molten metal. The heat derived is sufficient to continue the refining action. After about 20 minutes a visual drop in flame occurs signaling the reaction end point. A sample is taken to check the temperature and composition. When these are correct the furnace is tilted again and tapped into a ladle. When the molten metal has been removed, the furnace is rotated in the opposite direction and the slag dumped. The furnace is then ready for its next charge.

2.1.3.2 Electric Furnace Process. The electric-arc furnace is a bowl-shaped vessel mounted on a toothed rocker that can be tilted for pouring. The top has cylindrical openings, through which three large electrodes are inserted to conduct electric current.

The furnace charge consists almost entirely of scrap. After charging, the top is swung into place and the electrodes are lowered into the furnace. The current is turned on and begins to form a pool of molten metal on the hearth. The charge then begins to totally melt from the bottom up by radiation, heat from the arc, and electrical resistance of the scrap. Impurities combine with the slag. In some cases an oxygen lance is used to speed the refining.

When the process is completed the power is shut off, electrodes raised and tap hole opened. The furnace is then tilted and the molten metal poured into a ladle. The slag is removed by a separate ladle, after the steel.

2.1.3.3 Open Hearth Process. A substantial amount of steel is still produced by the open hearth process, although it is being replaced by the basic oxygen and electric arc processes. The furnace uses are large dish-shaped hearth lined with refractory material. The raw materials, typically half scrap and half pig iron, are charged to the furnace from the front. In actual practice any ratio of hot metal and scrap may be and is often used. Limestone is added to produce a slag as in a blast furnace. First the limestone is added and then the scrap. Gas or liquid fuel is burned with air to produce the desired heat. The refining is hastened by using oxygen lances in some cases. When the proper temperature is reached the molten iron is added. The heat continues for up to eight hours and a final temperature of about 1650°C (3000°F). When ready, the steel is tapped into a ladle a poured into ingots or transferred for other purposes. The slag follows the steel into slag cars or ladles.

2.1.4 Steel Processing and Shaping

By far the greatest portion of metal produced by the various steelmaking processes ultimately reaches the rolling mills. It is generally in the form of ingots. To form ingots, molten metal is ladled from the furnaces into ingot molds resting on cars.

A newer method of forming molten steel is in a continuous caster. In this process molten steel is first poured from a ladle into an intermediate pouring vessel called a tundish. The tundish is equipped with nozzles to feed the molds. The mold is made out of copper and is internally water cooled. Rolls pull down the starting bar which assists in pulling the metal through the mold. The rate is slow enough so that the molten metal continuously solidifies into the desired form. The finished casting is additionally cooled by water sprays and is cut into desired lengths.

Ingots and bars are moved to soaking pits prior to hot rolling in the primary mills. In these pits the ingots are heated to a temperature of about 1200°C (2200°F). The steel is then easily rolled into blooms or slabs.

2.1.4.1 Primary Rolling Mills. The white-hot ingots are taken from the soaking pits to the primary mills where they are rolled into blooms, which have a square cross section, or slabs, which are of rectangular cross section.

The blooming mill is equipped with two or three rolls; thus the nomenclature a "two-high" or "three-high" mill. In a two-high mill the rolls revolve in opposite directions, gripping the ingot and pulling it between them while squeezing it into a thinner, longer shape. By reversing the direction of the rolls and reducing clearances between them, the steel can be passed back and forth until the desired dimensions have been obtained. In the three-high mill the rolls are not reversed; instead, the metal rests on tables that can be raised or lowered after each pass to the level between the two top rolls or the two bottom rolls. When finished, the bloom, or slab, while still red hot, is carried on conveyor rolls to a shear and cut to the desired length.

Before further hot working, surface imperfections are removed by "scarfing" or burning-off with oxygen lances. After this operation the slabs are taken to a reheat furnace to bring them back to suitable rolling temperatures.

2.1.4.2 Secondary or Finishing Mills. After they are brought back to rolling temperature, the blooms or slabs are ready to be finished into a final product. This includes strip, sheet, plate, bar and rod, tube, rails, structural shapes, and specially finished steels.

In the hot strip mill a reheated slab is passed through a two-high scale breaker to remove scale. Next, it enters the roughing stands composed of four mills with four rolls. While passing through these mills a large volume of water, steam or air at high pressure is blown over the surface to remove scale. The slab, which is now considerably longer and thinner, is ready for the finishing stands. Finishing stands may include six or more mills. They work the strip into a finely finished ribbon of steel. The finished strip then enters a coiler at about 980°C (1800°F) which winds it into a bundle ready for shipping.

When thin sheet having good surface and metallurgical properties are needed, cold reduction stands are used. Mills of from one to six stands can be used. The stands are carefully synchronized to absorb slack from strip elongation, and are capable of very fine roll adjustments.

Sheets that are thicker than 0.584 cm and 20 or more centimeters (0.230 inches and 8 or more inches) wide are known as plates. Plates are usually rolled from scarfed heated slabs in two-three- or four-high mills with four-high reversing mills being the most common. Similar procedures as with sheet rolling are followed. After shearing to size, the plates are cooled and prepared for shipping.

Tubes are made from blooms that are reheated and center-punched for piercing. At the piercing mill the bloom is gripped by rotating rolls and a hole is punched through the billet. A rough pipe with thick walls is produced and sent to the plug mill. The plug mill reduces the wall to the desired gauge while at the same time lengthening it. Finally, the reeler and sizing rolls make the pipe round and smooth, and make the walls of uniform thickness. Other processes roll strip or skelp into cylinders and weld the edge to form tube and pipe. There are several different types of bar and rod mills. Each is a hot rolling operation designed to handle the billet or rod as it is successively reduced in size. Many different arrangements of stands are in use and up to twelve may be used in the operations. Shears cut the final bars and rods into proper lengths, often six to twelve at a time after which they are either processed further or bundled for shipment. Structural shapes are produced similarly using rolls with specific groove designs.

If a precise gauge or very bright surface finish is desired, a final rolling of thin steel strips or sheets is often carried out in a Sendzimir mill. This specific cluster mill uses highly finished work rolls of small diameter, each supported by two series of back-up rolls. The mill is reversible and the strips are passed back and forth until the final desired thickness and finish is achieved.

2.1.4.3 Application of Protective Coatings. Correct surface preparation is the most important requirement for satisfactory application of protective coatings for steel. Without a properly cleaned surface the coatings will fail to adhere or to prevent rusting of the steel base. The coating performance is proportional to the degree of surface preparation. Several methods of surface preparation exist. Two basic techniques are mechanical and chemical surface preparation. Solvent cleaning, alkaline cleaning, flame cleaning, blast cleaning (abrasives), hand or power-tool cleaning and pickling methods are used. The most common method for removing scale and rust in large-scale operations, such as at integrated steel mills, is pickling in dilute solutions of sulfuric or hydrochloric acid. Nitric and hydrofluoric acid mixtures are also used for alloy and specialty steels. The time of pickling, and concentration and temperature of the solution, are varied depending upon the type of scale to be removed or the type of steel being pickled. The metal is exposed to the acid for as little time as possible to minimize attack on the steel itself. The acid treatment is followed by a cold water and hot water rinse then drying. Batchwise or continuous pickling processes are employed.

After surface cleaning or preparation, protective coatings are applied. Metallic coatings are most commonly used for steel although organic coatings are also used. Tin, zinc, and terne metal (lead plus tin) are typically used while nickel, chromium, cadmium, copper, aluminum, bronze, brass, silver, gold and lead are used to a lesser extent. Metallic coatings are commonly applied to steel surfaces by electrolytic or hot dip processes.

Tin plate represents one of the major items produced by the steel industry in the United States. About 7 percent of the total steel products shipped are tin plate. The largest use of tin plate is for containers. The sequence of operations in the manufacture of tin plate is as follows: slabs are heated and hot-rolled to coil form in the hot strip mill. The coils are continuously pickled and taken to cold-reduction mills where they are reduced to approximately the final desired gage. The cold-reduced steel is cleaned, annealed, and then temper-rolled or cold-reduced in coil form in preparation for the tinning operations. There are several methods of applying tin coatings, but the most common is the electrolytic process. A more uniform coating with less consumption of tin is achieved by this method. Metal from a coil of steel which has been hot and cold rolled, pickled, annealed, tempered, and given a final cleaning is passed as the cathode through an electrolyte composed of tin salts. Blocks of pure tin act as the anodes. The tin is gradually deposited on the steel. The plate as it emerges from the plating bath is a dull gray-white. To cause a bright luster and assure complete coverage, the coated strip is heated with a resultant uniform fusion of the tin coating. After heating it is directly water quenched and dried. A thin protective oil film is applied to prevent surface oxidation and to aid in subsequent handling.

Coating steel with zinc is a very effective and economical means or providing protection against corrosion. Zinc coatings are commonly applied by dipping or passing the article to be coated through a molten bath of the metal. This operation is termed "galvanizing," "hot galvanizing" or "hot-dip galvanizing" to distinguish it from zinc electroplating processes which are termed "cold" or "electro-galvanizing." Of all the common metals used for protective coating, zinc is the lowest cost per pound. With the exception of tin, it is used to protect a greater area of steel than any other coating metal. A continuous (strip) hot-dip galvanizing operation is generally used. The steel in coil form from the rolling mills is uncoiled and passed continuously through the galvanizing equipment. Continuity of operation is achieved by joining the trailing end of one coil to the leading end of the next.

2.2 Equipment Utilizing Lubricants, Oils, Greases or Hydraulic Fluids

Lubricant-type materials in the steel industry can generally be broken down as greases, lubricating oils, process oils and hydraulic fluids. Due to the variety of operations and the amount and size of equipment used, no other industry employs a more complete usage of lubricants. High and low temperatures, shock loading, exposure to water and abrasive materials, are some of the adverse conditions normally encountered. All types of motors, turbines, bearings, gears, and drives must be properly lubricated to keep the machinery functioning.

Greases, oils and hydraulic fluids are used in a multitude of purposes and locations in a modern integrated steel mill. A typical mill may have over 400,000 lubrication points using as many as 150 differing specifications for lubricants. In the sections which follow, various classes of lubricants are listed together with types of equipment to which they are applied. For more detail in any specific area of the mill, Appendix A has a detailed breakdown by area and application point. A similar but more detailed steel mill lubrication guide, prepared by Joseph Lykins is, "A Practical Guide for Lubricating A Fully Integrated Steel Mill" which is presented in Appendix C.

2.2.1 Greases

Grease is generally used under the following conditions: 1) where there is no way to retain oil for the parts being lubricated; 2) when the lubricant must act as a seal to prevent the entrance of dirt; 3) when a lubricant is seldom added; and 4) where speeds are low and pressures are high.

The main use for grease is in the rolling mills. This includes both primary and secondary operations. The amount of machinery and extreme operating conditions demand a constant use of grease in many different situations. Steelmaking operations, as well as the blast furnace area, also account for a large expenditure of this lubricant.

Typical greases used in the steel industry can be listed under the following generic categories:

- extreme pressure grease (EP)
- molybdenum disulfide grease
- roller bearing grease
- roll neck grease
- extra duty EP grease
- high temperature EP grease
- mill utility grease
- cup grease
- block grease

Extreme Pressure Grease - EP grease is used for normal operating temperatures of 66 - 93°C,(150 - 200°F) on backup-roll, work-roll, and table bearings; this includes conditions found on ball, roller and plain bearings. EP grease is applied in situations where steel-to-steel contact is involved. One of the largest uses of EP grease is for various components of the finishing mills. This includes tensioning and coiler mandrels, roll bearings and table bearings. Other uses are for the hot metal and slag cars, roll bearings on the continuous caster, and on the feeder and breaker in the sinter plant.

Molybdenum Disulfide Grease - Moly grease is used in slow-speed, plain-bearing, and sliding-surface applications operated under marginal lubrication conditions. General plant use of moly grease is limited. Specific applications are for the blast furnace hoist cables, BOF trunnion bearings, and open gears on the ore and limestone handling equipment.

Roller Bearing Grease - Roller bearing grease is a high-temperature multi-purpose grease used for ball and roller bearing lubrication. It is commonly used in conditions covering exposure to water, high and low temperatures, shearing, oxidation and rust. These conditions are encountered by bearings on electric motors, wheel, gear shafts, and conveyors. Applications include blast furnace motors, the tilting mechanism motor on the hot metal mixer, soaking pit door motors, and sinter machine couplings.

Roll Neck Grease - Roll neck grease is a mild EP grease used in the presence of large quantities of water. It is used in large amounts in the blooming mill, billet mill, slabbing mill, bar mill, and plate mill. It is typically used on the mill screwdown which is adjusted to control the height of the rollers.

Extra Duty EP Grease - Extra duty EP grease is used in locations where high operating temperatures are present (93 - 121°C,(200 -

250°F)) and high pressure metal-to-metal contact is involved. Normal uses are on backup-roll, work-roll, and table bearings. It is applied to ball, roll and plain bearings, and for general purpose lubrication in the presence of large quantities of water. These conditions are typically found on coke battery latches, bearings and rods, on the blast furnace distributor grease seals, and on the primary mill roll stands, table bearings and mill spindles.

High Temperature EP Grease - This is a high-temperature multi-purpose grease used as a ball and roller bearing lubricant. It is applied in a wide range of conditions such as, exposure to water, extreme temperatures, shearing, oxidation, rust and extreme pressure. These conditions are usually encountered by motor bearings, wheel bearings, heavy-duty mill bearings and pressure systems requiring good mobility at low temperatures. Coke battery door hinges and latches, blast furnace torpedo cars, and electric-arc furnace electrode guides, drives, and latches are normal locations. The open-hearth furnace uses high temperature lubricants for charging box wheels. Reheating furnace doors, rollers, and rails also use large quantities of this grease.

Mill Utility Grease - Mill utility grease is used for operating conditions found on ball, roller, and plain bearings, including roll necks, and general purpose lubrication in the presence of large quantities of water where adherence to metal is important. A common use for this grease is the coke oven guides where large amounts of lubricant are needed.

Cup Grease - Cup Grease is used for the hand lubrication of plain bearings and bushings where the grease feed is controlled by a spring-load, screw-type, grease cup. Cup grease is widely applied to all types of small motors and machines in all parts of the plant.

Block Grease - Block grease is a water-resistant hand packed grease generally applied to rolling-mill necks. Since it is manually applied, it is generally used in older rolling mills having a minimum of automatic feed systems.

2.2.2 Oils

Oils are used in the steel industry for a wide variety of purposes. Very simply, oils are used in all cases where operating conditions do not dictate the use of a grease.

A basic list of common oils is given as below:

- engine oils
- extreme pressure oils (EP)
- R & O oils
- rolling oils
- Sendzimir mill rolling oil
- protective coating oil

Engine Oils - This category includes, gasoline engine oil, turbine oil, automatic transmission fluid, circulating oil, and diesel engine oil. These are all variable viscosity oils used for the lubrication of plain bearings, slides, machine tool bearings, low or normal load enclosed gears, and pistons and cylinders in engines. Common applications are in automotive engines, diesel locomotives, turbines, and power transmission systems.

Extreme Pressure (EP) Oils - Extreme pressure oils are used in applications involving high pressure metal-to-metal contact. These lubricants are applied to most gears unless they require grease lubrication. Examples are water pump gear drivers, blast furnace and crane reduction drives, rolling mill screw downs and shear drives, and rolling mill coiler and drives.

Rust and Oxidation Inhibited (R&O) Oils - These R&O oils are used in applications that require oil but do not require EP characteristics. Frequently they are used in recirculating systems.

Typical applications are in plain Babbit, Mesta or Morgoil bearings in rolling mills, plain bearings in turbo blowers, air compressors and steam turbines, and in back-up roll bearings.

Rolling Oils - Rolling oils are not usually classified as lubricants, but they are used in large quantities in the cold processing of sheets, plates, strip steel or tin plate to reduce roll wear and improve the finish of the steel. These oils are specially formulated for each application and are not at all similar to lubricating oils. Some steel mills also use rolling oils in hot rolling operations.

Sendzimir Mill Rolling Oil - This is a low viscosity, oxidation and rust resistant oil. It is a well refined oil designed for use in the Sendzimir Mills, which will serve the dual function of roll oil and lubricant for mill components. Different types of oils are used for different steels. Low viscosity mineral oil is used for heavy gage, fatty polar types for stainless, paraffinic slushing oils for carbon and silicon, and palm oil for tin plate.

Protective Coating Oil - There are a wide variety of products that are used to protect finished products against corrosion, water, and extreme temperatures. Low viscosity mineral oils with polar additives and inhibited petroleum oils are commonly used for indoor storage. Heavy petroleum or asphaltic coatings and varnishes are used for outdoor applications.

2.2.3 Hydraulic Fluids

Hydraulic fluids are generally oil-based products and come in a slightly lesser variety than lubricating oils and greases. Some typical products in use include:

- inverted emulsions
- phosphate ester fluids
- water-glycol fluids

inhibited hydraulic oil
extra-duty anti-wear hydraulic oil

Inverted Emulsions - Inverted emulsions are stable water-in-oil emulsions used for fluid power systems that are subject to fire hazards. They are not suitable above 66°C (150°F), or above 10 megapascals (1500 psi), or in systems that are prone to shock loads or high shear stresses. They are the least expensive fire resistant hydraulic fluid. Inverted emulsion fluids are used in coke battery pushers, hot strip mill coil conveyors and the primary and secondary mill roll balance systems.

Phosphate Ester Fluids - Phosphate ester fluids are also used in hydraulic systems that are subject to fire hazards. They are suitable for high-pressure operating systems (to 34 megapascals) (5000 psi) and high temperatures to 107°C (225°F). They are the most expensive type of fire resistant hydraulic fluid. A normal application is in the hydraulic systems of tractors used in the removal of pit slag. Optional uses are in the hydraulic systems on the scarfing machine, soaking pits, rotary furnaces, and askania regulators.

Water-Glycol Fluids - Water-glycol fluids are also used chiefly in areas subject to fire hazards. They are not suitable for power systems operating above 66°C (150°F) or above 14 megapascals (2000 psi). Typical uses are in the open-hearth dolomite machine, the electric-arc furnace tilting mechanism and electrode system, and the continuous caster pinch-roll and cut-off torch systems.

Anti-Wear Hydraulic Oil - Anti-wear hydraulic oils are normally used in all precision, stationary, hydraulic units, and where there is no fire hazard.

3. OILS, GREASES AND HYDRAULIC FLUIDS

The iron and steel industry uses a large number, frequently more than 100, different lubricants in the making, shaping and treating of steel products. Different lubricants must perform under different conditions: at high temperatures, under high pressure, in the presence of water or steam, or they must be fire resistant.

The combination of requirements such as these determine the number and nature of lubricants that must be used. Frequently, the desired properties are achieved by using additives and a base lubricating stock. Approximately half of the lubricants produced in the United States are used in automobiles[4] and 36 percent in industrial lubrication. Oil and grease consumption in the steel industry has been estimated at 378,500,000 liters (100,000,000 gal) per year which represents 3 to 5 percent of the entire U.S. lubricant production.[4]

In this chapter, oils, greases and hydraulic fluids are discussed according to their chemical composition. The chemical composition of additives is also discussed and the toxicities of all materials are reviewed. A brief description of lubricant purchasing practices is provided at the end of the chapter.

3.1 Classification

Lubricants may be classified in two different ways: (1) according to lubricating characteristics, and (2) according to chemical composition. The former classification is most often used because it enables the lubrication engineer or maintenance worker to select the proper lubricant for the equipment that is being serviced. The latter classification is more useful in this study because the disposal, reclamation and toxicity of a lubricant are determined by its chemical composition rather than by its viscosity, viscosity index and other physical properties. Both classification schemes are discussed below.

3.1.1 Classification According to Lubricating Properties

A typical classification scheme for steel mill lubricants is shown in Tables 3-1 and 3-2. Forty-two lubricating oil and twenty-three grease classifications are shown along with the pertinent characteristics of each.[4] Viscosity, resistance to oxidation, water separation, detergency, performance at extreme pressures and temperatures, and price of the lubricant are major factors that define each category. Categories are given names such as "circulating engine oil," "hypoid gear oil," "general purpose grease," "antiwear hydraulic oil," etc. that are helpful in describing families of lubricants. But within each of these categories several specific lubricants are usually manufactured in a range of viscosities or other properties. The same types of lubricants may be available from several manufacturers.

The categories as listed in Tables 3-1 and 3-2 are too general to be useful to someone who wants to select the correct lubricant for a particular piece of equipment or for a purchasing agent who must replenish stocks of lubricants. For this latter purpose steel mills have assigned identification numbers or classification numbers that are used internally as a means of identifying each individual lubricant. Examples of such schemes are given in Tables 3-3 and 3-4. Table 3-3 shows the United States Steel Corporation classification which uses a three-digit requirement number to identify each of 101 different lubricants. United States Steel publishes the Lubrication Engineers Manual[5] that lists the lubricant performance requirements corresponding to each requirement number and gives directions for performing tests to see if specifications are met. The Kaiser Steel Corporation lubricant index is also presented in Table 3-4. Kaiser Steel maintains detailed listings stating the physical properties, performance requirements, types of containers, and container labeling schemes for each of the 93 lubricants in this list. Youngstown

Table 3-1. TYPICAL LUBRICATING OILS USED BY VARIOUS STEEL COMPANIES

Usual identity	Approx viscosity range, SUS at 100 F	General description	Recommended or preferred application	Number of companies reporting use
1. Spindle oil	Under 100	Turbine quality	Precision shop tools	1
2. Engine oil—low viscosity	Up to 450	Ordinary stability, water separation	Hand oiling, once-through sight feed	5
3. Engine oil—high viscosity	450/2,000	Ordinary stability, water separation	High loss hydraulic and circulating systems	1
4. Turbine oil	Under 500	High oxidation and rust resistant, water separation, top quality	Steam turbines, machine tools; Precision hydraulic machines, motor rooms	5
5. Turbine and circulating oil	Under 500	Second-line turbine oil with good R and O and water-separating qualities	Ring-oiled bearings, circulating systems; Lacking severe operating conditions	5
6. Circulating engine oil	Up to 2000	Good stability, water separation	High-loss circulating systems	3
7. Circulating oils	Over 500	Good stability, high-degree water separation	Backup roll oil-film bearings, enclosed gears	3
8. Black oil (at 210 F)	80-300	Asphaltic residual oil	Hand oiling, skids	4
9. Pale paraffin oil	....	Ordinary stability—pale oil	Slushing, flushing oil for systems	3
10. Cylinder oil—unfiltered	2,000 and up	Straight mineral, steam refined	Non-EP enclosed-gear lubricant, rough oiling	2
11. Cylinder oil—filtered	2,000 and up	Bright stock	Enclosed gearing where good quality desired	6
12. Cylinder—filtered, compounded	2,000 and up	Bright stock and acidless tallow	Steam cylinder lubrication—worm gearing	1
13. Cylinder—unfiltered, compounded	2,000 and up	Dark oil and acidless tallow	Steam cylinder lubrication—worm gearing	1
14. Motor oil—API, ML	150/1,250	Good stability	Automotive engines, air compressors, light service	2
15. Motor oil—API, MM	150/1,250	Good stability	Automotive engines, air compressors, medium service	2
16. Motor oil—API, MS	150/1,250	Good stability	Automotive engines, air compressors, severe service	3
17. Detergent diesel and motor—API, DG	150/1,250	Good stability and detergency	Diesel and automotive engines, light service	3
18. Detergent diesel (API-DM)	150/1,250	Good stability and detergency	Diesel and automotive engines, low-S fuel	2
19. Detergent diesel (API-DS)	150/1,250	Good stability and detergency	Diesel and automotive engines, high-S fuel	2
20. Caterpillar, Series 3	150/1,250	High stability and detergency	Caterpillar engines, high-S fuel	2
21. Diesel locomotive	....	EMD requirements	Locomotive service	3
22. Way lubricants	150/1,000	Compounded oil with good stick-slip	Machine tool ways	3
23. Hydraulic-slideway oils	150/300	Low-viscosity compounded oil with good stick-slip	Combination hydraulic and way oils—machine tools	1
24. Gear oil	500/4,500	Non-EP—SAE designations	Enclosed gearing	1
25. Hypoid gear oil	500/4,500	Active antiweld EP for high loading	Heavily loaded spiral bevel and hypoid gearing	3
26. Car journal oil	150/300	AAR requirements	Railroad-car journal bearings	3
27. Pneumatic tool oil	100/600	Wetting agent and emulsifier	Pneumatic tool cylinders	2
28. Light-duty mineral metalworking fluid	40/150	Fatty oil compounding		3
29. Medium-duty mineral metalworking fluid	100/300	Low sulfur, low chlorine compounding		
30. Heavy-duty mineral metalworking fluid	150/500	Active sulfur, high S, high Cl compounding		3
31. Conventional soluble oil	100/1,500	Emulsifier, rust inhibitor, low activity	Used as required	4
32. Heavy-duty soluble oil	150/2,350	Emulsifier, rust inhibitor, S, Cl, or fats added		4
33. Chemical cutting fluid	Various	Synthetic, usually water soluble		1
34. Extreme-pressure gear oil	300/17,000	High load-carrying capacity, good stability, water separation	Mill drives, pinions, screws, and nuts	7
35. Roll-neck spray oil	300/1,000	Same as gear oil plus adhesiveness in presence of water	Roll-neck bearings, gearing	2
36. Open-gear lubricant (non-EP)	750 at 210 F up	Normal temp; shock resistant, water resistant	Open gearing, chains, skids	3
37. Open-gear lubricant (EP)	750 at 210 F up	Adhesive, high load capacity, water resistant	Heavily loaded open gearing, chains, etc.	3
38. Hydraulic (inverted emulsion)	200/450	Nonseparating, low cold test, fire resistant	Specified by type of pump	2
39. Hydraulic (water glycols)	150/300	Fire resistant, good wear resistance	Specified by type of pump	2
40. Hydraulic (phosphate ester types)	90/250	Fire resistant, good wear resistance	Specified by type of pump	2
41. Antiwear hydraulic oil	Under 500	Inhibited oil with antiwear additives	High-pressure hydraulic service specified by pump	4
42. Mist oils	150/1,500	Good misting, non-gumming	High-speed antifriction bearings	4

SUS = Saybolt Universal Seconds: Viscosity conversion tables are available in chemistry or lubrication handbooks.

Table 3-2. TYPICAL LUBRICATING GREASES AND COMPOUNDS USED BY VARIOUS STEEL COMPANIES

Usual identity	Pertinent information	General requirements	Recommended or preferred application	Number of companies reporting use
1. Asphaltic/residual base—EP	6,000 at 100 F	Various soap gelling agents plus asphaltic oil	Couplings, screwdowns, cables	1
2. Block grease—non-EP	Usually Ca soap	NLGI-4 to 6½, 200 at 350 F mp (no lead or graphite)	Roll-neck lubrication for hand-packed design	3
3. Block grease—EP	Usually Ca soap	NLGI-4 to 6½, 260 at 350 F mp with lead or graphite	Heavily loaded roll necks, old hand packed design	3
4. Cup grease—light duty	Oil viscosity under 400 SSU	Normal temp, water resistant	Light loads, general grease-cup lubrication	3
5. Cup grease—heavy duty	Oil viscosity over 400 SSU	Normal temp, water resistant	Medium loads, general grease-system lubrication	2
6. General purpose—stringy	Stringiness added	Ca soap, normal temp, water resistant, elastomer	Centralized systems, where stringiness desired	1
7. Graphited roll-neck grease	Oil viscosity 1,000 at 100 F	Ca soap, medium temp, water resistant	Roll-neck bearings, centralized grease systems	3
8. High-temp graphited roll-neck grease	Oil viscosity 1,000 at 100 F	Sodium soap, graphite, for high operating temp	Roll-neck bearings, system grease—bronze slippers	2
9. Standard EP roll-neck grease	Oil viscosity 1,000 at 100 F	Ca soap, leaded, water resistant	Heavily loaded table roller or plain bearings and roll-neck bearings	7 1
10. Standard non-EP roll-neck grease	Oil viscosity 1,000 at 100 F	Similar to cup grease heavy duty, heavy base oil, no EP	Roll-neck bearings, wire rope	2
11. Extreme temp EP	Calcium complex Aluminum complex	Dropping point (500 F) EP, water resistant	High, continuous operating temp over 250 F	5
12. Inert base	Non-soap gelling	No dropping point, water resistant	High, continuous operating temp over 250 F	3
13. Inert base EP	Non-soap gelling	Same, but leaded for extreme pressures	Same but for high loads	1
14. Extra duty	Lithium soap	High temp, water resistant, mechanically stable	Antifriction and plain bearings (150-250 F)	2
15. Extra duty EP	Lithium soap	High temp, water resistant, EP	Same but for high loads	6
16. Ball and roller bearing grease	Mixed base	Fibrous, medium temp, oxidation and shear stability	Antifriction bearings	3
17. Mining machine lubricant	Calcium soap	Semifluid, multipurpose, water resistant, EP	Mining machine gears and bearings	2
18. Car journal grease	Calcium soap	Semifluid, water resistant, wool yarn horsehair	Journals designed for grease packing	2
19. Drawing and forging	Various	Semifluid with high graphite and/or fat	Forging compounds	1
20. Petrolatum	....	100–130 F mp	Slushing, rope lubrication, rust prevention	2
21. Pipe thread grease	API specifications	Prevent leakage in API casing and tubing joints, zinc, graphite, etc., filler	Pipe threads and couplings	2
22. Roller bearing grease	Sodium base	Fibrous, high temp, non-water-resistant	Antifriction bearings, no water presence	5
23. Moly grease	MoS_2 filler	3 to 10% MoS_2 in various soap greases	Oscillating, highly loaded bearings, some gearing	3

Saybolt Universal Seconds: Viscosity conversion tables are available in chemistry or lubrication handbooks.

Table 3-3. LUBRICANT CONSOLIDATION PROGRAM

Basic Performance Classification

The number assigned to these requirements have been established for identification within U. S. Steel and have no significance outside of U. S. Steel.

USS REQ. NO.	COMMON IDENTIFICATION	USS REQ. NO.	COMMON IDENTIFICATION
080	Diesel Fuel	209	Unclassified
081	Diesel Fuel No. 2 — Convertol	210	Compounded Cylinder Oil
085	Coke Plant Wash Oil	211	Cylinder Oil (Less than 5% ATO)
110	Engine Oil	219	Oil Unclassified
116	Non-Inhibited Hydraulic Oil	220	Extreme Pressure Oil
119	Unclassified	221	Hypoid Gear Oil
120	Turbine Oil	222	Extra Duty Gear Oil
122	Ford Type F	225	E. P. Open Gear Compound
123	Auto. Transmission Fluid, Dexron	226	E. P. Solvent Cut-Back Open Gear Compound
124	Hydraulic Transmission Fluid, Type C-12	227	Dipper Handle Lube
125	Circulating Turbine Oil	229	Unclassified
126	Inhibited Hydraulic Oil	230	Black Oil
129	Unclassified	233	AAR Car Oil
130	Circulating Engine Oil	235	Open Gear Compound
133	Elastomer Oil	236	Solvent Cut-Back Open Gear Compound
134	Way Lubricant	239	Unclassified
135	Circulating Oil	299	Special Oil Unclassified
136	Extra Duty Circulating Oil	300	Cup Gr. (100 to 400 SSU @ 100F)
139	Unclassified	301	Cup Gr. (400 to Cyl. Stock @ 100F)
140	API Service CA	309	Unclassified
141	API Service CA	310	Sodium Base Roller Brg. Grease
142	API Service CB	319	Unclassified
143	API Service CC	330	Mixed Base Roller Brg. Grease
144	API Service CC	339	Unclassified
145	API Service CC	340	Graphited Roll Neck Grease
146	Caterpillar Series 3	343	Heavier Than Water Grease
148	Locomotive Diesel Engine Oil	346	Molly Grease
149	Unclassified	349	Unclassified
150	Pale Paraffin Slushing Oil	350	Extreme Pressure Grease
151	Sendzimir Mill Rolling Oil	352	Extra Duty E. P. Grease
152	Compounded Quenching Oil	355	Extreme Temperature E. P. Grease
153	Compounded Rust Preventative	359	Unclassified
154	Coal Spray Oil	370	High Temperature E. P. Grease
159	Unclassified	371	Ball & Roller Bearing Grease
160	Mineral Metalworking Fluid	372	Extreme Temperature Grease
161	Hvy. Duty Min. Metalworking Fl.	373	Mining Machine Lubricant
162	Soluble Metalworking Fluid	374	AAR Journal Roller Bearing Grease
163	Hvy. Duty Sol. Metalworking Fl.	375	Mill Utility Grease
167	Water Hydraulic Additive	379	Unclassified
168	F. R. Fluid Invert Emulsion	400	Block Grease
169	Unclassified	405	General Hoisting Heavy Gauge Wire Lub.
170	F. R. Fluid Phosphate Ester	406	General Hoisting Light Gauge Wire Lub.
171	F. R. Fluid Glycol-Water Base	409	Unclassified
174	Heavy Duty Brake Fluid	410	Impregnated Journal Compound
175	Synthetic-Petroleum Hydraulic Fluid	411	Replenishing Lubricant
179	Unclassified	490	Thread Compound — API Modified
190	Insulating Oil	491	Thread Compound — API Silicone
191	Penetrating Oil	498	Petrolatum
196	Pneumatic Tool Oil	499	Special Grease Unclassified
199	Miscellaneous Oil Unclassified	800	Asphalt Road Oil, Work Oil, Grade Oil, etc.
200	Cylinder Stock Oil		

Table 3-4. INDEX TO STANDARD SPECIFICATIONS FOR LUBRICANTS

KSC SPEC NO.	TITLE
60000	MULTI-PURPOSE E.P. WATER-PROOF MOLY GREASE
60001	MILL GREASE, WASH RESISTANT
60002	MILL GREASE, MULTI-PURPOSE
60003	GREASE, BALL & ROLLER BEARING, LIGHT
60004	MILL GREASE, MOLYDISULFIDE
60005	MILL GREASE, MOLY SPINDLE LUBE
60006	MILL GEAR GREASE, FLUID
60007	LOW TEMP. G.P. GREASE
60010	E.P. WATER-PROOF GREASE
60050	GREASE, BALL & ROLLER BEARING
60051	GREASE, HIGH TEMPERATURE
60056	GREASE, HIGH TEMPERATURE (PRECISION MACHINERY)
60100	OPEN GEAR LUBRICANT, DILUTED
60103	OPEN GEAR LUBRICANT, LIGHT
60105	OPEN GEAR LUBRICANT, HEAVY
60106	OPEN GEAR LUBRICANT, X-HEAVY
60108	OPEN GEAR LUBRICANT, ULTRA-HEAVY
60109	MOLY CHAIN OIL & WIRE ROPE DRESSING
60200	NON-LEAD E.P. INDUSTRIAL GEAR OIL, LIGHT
60201	NON-LEAD E.P. INDUSTRIAL GEAR OIL, MEDIUM
60202	NON-LEAD E.P. INDUSTRIAL GEAR OIL, HEAVY
60203	NON-LEAD E.P. INDUSTRIAL GEAR OIL, X-HEAVY
60204	NON-LEAD E.P. INDUSTRIAL GEAR OIL, ULTRA-HEAVY
60205	NON-LEAD E.P. INDUSTRIAL GEAR OIL, X-LIGHT

KSC SPEC NO.	TITLE
60249	MULTI-PURPOSE E.P. GEAR OIL SAE-80
60250	MULTI-PURPOSE E.P. GEAR OIL SAE-90
60251	MULTI-PURPOSE E.P. GEAR OIL SAE-140
60300	MORGOIL OIL - MEDIUM
60301	MORGOIL OIL - HEAVY
60305	BEARING OIL - HEAVY (MIST)
60360	CYLINDER OIL - MEDIUM
60400	HYDRAULIC OIL, A.W. LIGHT
60401	HYDRAULIC OIL, A.W. MEDIUM
60402	HYDRAULIC OIL, ASKANIA
60403	HYDRAULIC OIL A.W. LOW TEMPERATURE
60450	HYDRAULIC FLUID - WATER GLYCOL
60460	HYDRAULIC FLUID - INVERT EMULSION
60500	TURBINE OIL, LIGHT
60501	TURBINE OIL, MEDIUM
60502	TURBINE OIL, MEDIUM HEAVY
60503	TURBINE OIL, HEAVY
60550	AIR COMPRESSOR OIL, MEDIUM
60581	MOTOR OIL SAE 10W/30
60582	MOTOR OIL SAE 20W/40
60600	MOTOR OIL, HD, SAE-10W
60601	MOTOR OIL, HD, SAE-20W/20
60602	MOTOR OIL, HD, SAE-30

KSC SPEC NO.	TITLE
60603	MOTOR OIL, HD, SAE-40
60604	MOTOR OIL, HD, SAE-50
60605	RAILROAD OIL, SAE-40
60650	MOTOR OIL, S-3, SAE-10W
60651	MOTOR OIL, S-3, SAE-20W/20
60652	MOTOR OIL, S-3, SAE-30
60653	MOTOR OIL, S-3, SAE-40
60680	AUTOMATIC TRANSMISSION & TORQUE CONVERTER FLUID (DEXRON-II)
60681	AUTOMATIC TRANSMISSION FLUID TYPE F (2-P)
60682	HYDRAULIC TRANSMISSION FLUID-TYPE C-2
60700	CUTTING OIL, TRANSPARENT
60701	CUTTING OIL, DARK
60750	SOLUBLE OIL
60751	SOLUTION OIL, E.P.
60752	WATER-BASE CHEMICAL GRINDING COOLANT
60754	CONVEYOR SPRAY OIL
60755	WATER EXTENDABLE SYNTHETIC GRINDING COOLANT
60783	HYDRAULIC BRAKE FLUID
60800	JOURNAL OIL, HEAVY
60801	MILL OIL, HEAVY
60802	E.P. WAY OIL, LIGHT
60803	E.P. WAY OIL, HEAVY
60804	JOURNAL OIL, LIGHT
60809	ROCK DRILL OIL, E.P.

KSC SPEC NO.	TITLE
60810	SPINDLE OIL, X-LIGHT
60811	SPINDLE OIL, LIGHT
60850	DIESEL FUEL OIL
60851	DIESEL FUEL LOW TEMPERATURE
60854	GAS, REGULAR
60855	GAS, PREMIUM
60856	KEROSENE
60857	GAS, UNLEADED REGULAR
60862	PAINT THINNER

60900	FURNACE SEAL OIL
60901	FURNACE OIL
60902	BUNKER FUEL OIL
60903	INSULATING OIL - INHIBITED
60909	METAL PROTECTIVE OIL
60910	COAL SPRAY OIL
60916	WASH OIL

KSC STANDARD NO.	
1501	OXIDATION AND STABILITY TEST FOR LEADED GEAR OILS
1502	WATER SEPARATION TEST FOR CIRCULATING OILS
1503	SHEAR STABILITY TEST FOR LUBRICATING GREASES
1504	WATER LEACH TEST FOR LUBRICATING GREASES
1505	STABILITY TEST FOR DIESEL FUEL
1506	MARKING OF LUBRICANT CONTAINERS AND GENERAL INFORMATION

Sheet and Tube uses approximately 120 different lubricants which are broken down into thirty-six basic specifications and are obtained from twenty different suppliers. Other steel mills have similar requirements and procedures.

Although most steel mills have their own classification schemes, all systems have much in common. Lubricants are generally identified and classified by similarities in their performance specifications, chemical or physical properties, or types of service. Indexes or classification lists are used internally as a means of identifying lubricants. Code numbers are assigned enabling more efficient and simplified procurement, storage, handling and record keeping. Lubricant application charts and schedules typically incorporate the code scheme. The classification of lubricants by code number enables lubrication engineers and plant operators to readily identify duplication of brand name products. Records of lubricant purchase and/or application are frequently maintained in computers, and code numbers are used for these records. Delivery of lubricants in containers color coded and labeled only by the steel mill's code number is often required. This procedure may avoid certain plant operator biases toward a given brand or trade name product.

Some steel mills may use more types of lubricants than are really essential, since equivalent results may be obtained with several different lubricants. Other mills have made efforts to consolidate and simplify their lubricant usage whenever possible. Making changes in lubricant recommendations on major producing units is generally a slow process. The underlying reasons are traditional conservatism (experimentation and experimental mistakes may be costly), divided responsibility in some cases (different departments are often responsible for the selection, purchase and application of lubricants), and reluctance to experiment where mill performance appears to be adequate with the existing lubricant.

Nevertheless, interest toward consolidation of lubricants has brought multi-purpose lubricants into favor in most steel mills. The trend has been towards centralized and automatic lubricant application systems which, if designed and maintained properly can simplify lubrication efforts. Although consolidation of lubricants may result in an upgrading of specifications or properties, especially where greases are concerned, and a resulting higher average cost per gallon or pound of lubricant purchased; these increased costs are often offset by other savings, such as reduced lubricant purchase, storage and handling requirements.

3.1.2 Classification According to Chemical Constitution

The average lubrication engineer at a steel mill has little use for a classification scheme based on the chemical composition of the lubricant. However, for this study such a scheme is useful because it relates to the ultimate fate of these lubricants and to the toxicities of the end products. By far the greatest quantities of lubricants -- 97% of the worldwide total -- are derived from petroleum. Petroleum is, of course, a mixture of hundreds of different hydrocarbons along with small amounts of compounds that contain nitrogen, sulfur, oxygen and certain metals. Table 3-5 shows how the relative quantities of the various components affect the properties of the lubricant.[6]

The exact composition of the base oil depends on the oil field where it was produced, but these differences are usually small (see Table 3-6).[6] Base oils are subjected to various refining processes to alter their properties, usually by removing some minor components of the base oil. However, all petroleum-based lubricants are sufficently similar with respect to their chemical composition that they can be treated as a single class for the purpose of this discussion.

Table 3-5. BASE OIL COMPOSITION AND DEPENDENT PROPERTIES

Component	Properties affected by presence in oil
Hydrocarbons: Paraffins Naphthenes Aromatics	Bulk properties such as -- Viscosity, V.I. Gravity Pour point Aniline point Unsulfonated residue Solvency Oxidation: Stability and response to antioxidants Volatility Response to V.I. improvers
Nonhydrocarbon: Nitrogen compounds Sulfur compounds Oxygen compounds Organometallic compounds	Oxidation: Stability and response to antioxidants Demulsibility Lubricity Solvency EP properties Foaming Rusting

Table 3-6. COMPOSITION ANALYSIS

Type of compound	California paraffinic 480 neutral 90 V.I.	Hydro-treated 500 neutral 101 V.I.	MC paraffinic 350 neutral 97 V.I.
n-d-M analysis:			
Percent carbon atoms in aromatic rings	5.5	3.5	2
Percent carbon atoms in naphthene rings	32	26.5	33
Percent carbon atoms in paraffin chains	62.5	70	65
Mass spectrometer analysis (volume percent):			
Paraffins	11.5	14.8	13.9
Cycloparaffins:			
1 ring	19.4	19.6	15.9
2 rings	11.8	19.7	18.0
3 rings	15.6	11.9	14.6
4 rings	15.3	6.7	10.5
5 rings	10.6	8.2	11.6
6 rings	0	0	0
Alkylbenzenes	4.8	7.5	5.7
Indanes-tetralins	2.6	2.3	1.7
Benzodicycloparaffins	2.7	2.3	2.4
Naphthalenes	.7	.6	.5
Acenaphthenes	.6	.5	.2
Fluorenes	0	0	0
Phenanthrenes	1.1	1.8	.9
Pyrenes	1.1	1.3	.7
Chrysenes	2.3	1.8	2.7
Benzothiophenes	.3	0	.2
Dibenzothiophenes	.1	.5	.5
Naphthobenzothiophenes	0	0	0
Summary:			
Paraffins	11.5	14.8	13.9
Cycloparaffins	72.2	66.1	70.6
(3 rings and larger)	(41.5)	(26.8)	(36.7)
Aromatics	15.9	18.6	14.8
(3 aromatic rings and larger)	(5.1)	(5.4)	(4.5)
Thiophenes	.4	.5	.7
Total saturates	83.7	80.9	84.5

V.I. = Viscosity Index - an empirical number indicating the rate of change in viscosity of an oil within a given temperature range.

A suggested classification scheme based on the chemical composition of the base oil is given below:

A. Petroleum-based

B. Non-petroleum based

   1. Natural oils
      a. Tallow
      b. Vegetable oils

   2. Synthetic lubricants
      a. Phosphate esters
      b. Glycols
      c. Others

Most of the natural oils are mixtures of closely related substances, but for present purposes they can be treated as single classes. The synthetic lubricants, on the other hand, are usually single chemical species, and the various subclasses of synthetic lubricants differ widely from each other.

In a typical steel mill, synthetic lubricants may be used as fire-resistant hydraulic fluids, and natural oils are used in large quantities as rolling oils at all steel mills that produce sheet and tin plate. All other lubricants, hydraulic fluids and process oils used by a steel mill are petroleum-based products.

3.2 Additives

An additive can be defined as a substance that reinforces some desirable property already possessed to some degree by the oil, or imparts a new and desirable property not originally present. Although several hundred materials have been developed as additives, their principal functions can be grouped into eight categories:

- reduce oxidative degradation of lubricant
- lessen deposition of harmful deposits
- minimize rust and corrosion
- control frictional properties
- reduce wear
- prevent destructive metal-to-metal contact
- alter viscosity or viscosity index
- reduce tendency to form stable foams

In the trade, a group of descriptive terms is used to identify additives and approximately describe their use. For example, antioxidant, corrosion inhibitor, rust inhibitor, extreme pressure (EP) agent, antistain agent, antifoam agent, antiwear agent, V.I. improver, and detergent are all commonly used terms. Some additives have more than one function, so it is not possible to identify specific additives from these descriptive terms, but Table 3-7 gives a listing of additives used in steel mill lubricants and their functions.[7]

Additive formulations are usually patented, and lubricant manufacturers consider their particular formulas to be proprietary. Nevertheless, certain general facts are available regarding additive composition and usage. The specific chemical compositions of the most widely used additives are given below:

Lithium-12-hydroxy stearate is used as a thickening agent in most steel mill greases in quantities averaging about 6% of the total weight of the grease. In most steel mills, this additive is used in greater quantity than any other additive. Molybdenum disulfide is used in addition to lithium-12-hydroxy stearate in certain greases for oscillating mechanisms and highly loaded bearings. It is added in quantities up to 4 or 5% by weight to form specialty greases that

Table 3-7. TYPES OF STEEL MILL LUBRICANTS AND THE ADDITIVES THEY MAY CONTAIN

Steel Mill Lubricants	Amount of Lubricant Used	Type of Additive	Purpose of Additive	Types of Compounds Used
GREASES				
Extreme Pressure (EP)	moderate	thickener	improve consistency	calcium or lithium soaps
		EP agent	prevent welding and galling at high pressure	sulfur, phosphorus compounds, sometimes lead compounds
		antioxidant	prevent oxidative degradation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
Molybdenum Disulfide	small	same as for EP grease plus another EP agent	prevent welding and galling during high pressure, slow speed applications	same as for EP grease plus molybdenum disulfide
Roller Bearing	moderate	thickener	improve consistency	calcium or lithium soaps
		antioxidant	prevent oxidative degradation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
High Temperature	small	thickener	improve consistency	bentonite, lithium or aluminum soaps
		EP agent (optional)	prevent welding and galling at high pressure	organic compounds containing sulfur or phosphorus
Cup	very small	thickener	improve consistency	calcium soap
		graphite	assist in lubrication	graphite
OILS				
Engine	small	pour depressant	permit easy cold weather starting	organic polymers
		Viscosity Index improver	maintain good lubricant film at high temperatures	organic polymers
		anti-foam compound	minimize foaming	silicone polymers
		detergent	keep engines clean	soaps of alkyl phenates, sulfonates and phosphonates
		antioxidant	prevent oxidative degradation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	prevent bearing corrosion	organic cpds. of many kinds
		dispersants	prevent sludge accumulation	high molecular weight alkyl succinimides and thiophosphonates
		EP (anti wear) agent	prevent excessive wear and scuffing of valve train	zinc dialkyldithiophosphate
Extreme Pressure (EP)	large	anti-foam compound	minimize foaming	silicone polymers
		antioxidant	prevent oxidative degradation	organic cpds. usually containing sulfur, phosphorus or nitrogen
		corrosion inhibitor	minimize rust and corrosion	organic cpds. of many kinds
		rust inhibitor	prevent rust of metal parts	sulfonates, amines, phosphates, certain acid derivatives
		EP agent	prevent welding and galling at high pressure	organic compounds containing sulfur or phosphorus
Rolling Oils	very large	no additives		
Protective Coating	variable	rust inhibitor	prevent rust of metal parts	sulfonates, amines, phosphates, certain acid derivatives
HYDRAULIC FLUIDS				
Inverted Emulsion	moderate	no additives		
Water-Glycol	small	no additives		
Anti-wear	moderate	same as engine oils without detergents	(see under "Engine Oils" above)	(see under "Engine Oils" above)

constitute 10 to 30% of the total grease consumption in typical steel mills. Some high temperature greases contain clays such as bentonite or calcium soaps in place of the lithium-12-hydroxy stearate as a thickener. These greases are usually used in small quantities in various operations associated with iron and steel production. Greases for extreme pressure applications contain sulfurized and phosphorized fatty oils in quantities equivalent to .03% phosphorus and .8% sulfur in the grease. Extreme pressure greases usually constitute 30 or 40% of the total greases used in a steel mill.

Zinc dialkyl dithio phosphate $\left(\begin{array}{l} RO \searrow \\ RO \nearrow \end{array} P \begin{array}{l} \nearrow S \\ \searrow SZn_{1/2} \end{array}\right)$ is widely used in oils as a mild EP additive and corrosion inhibitor in amounts averaging .8 percent by weight. In most steel mills this additive ranks second with respect to total quantity used -- outranked only by lithium-12-hydroxy stearate. It also functions as an antioxidant, but a small percentage of oils contain 2,6-di-t-butyl-4-methyl phenol (BHT) instead.

Oils for extreme pressure use contain the same kinds and quantities of extreme pressure additives that were mentioned in the paragraph above dealing with greases. Lead naphthenate was formerly used as an extreme pressure additive, but it is being phased out because of poor stability to heat and oxidation as well as its adverse environmental impact. Some lead naphthenate gear oils are still in use in mills where there is reluctance to abandon a lubricant that has performed satisfactorily in the past, but most lubrication engineers believe that nonleaded gear oils can be used with equivalent or superior results.

Other kinds of additives such as rust inhibitors, V.I. improvers, antifoam compounds, detergents and dispersants are used in extremely small quantities in the steel industry. As will be shown in Section 9, the usage of these minor additives is so small that no material balance study was done for each of them.

In general, lubricants, process oils, and hydraulic fluids that are not petroleum-based do not contain additives. Rolling oils, which are used in large quantities in cold rolling operations, are derived from palm oil, tallow or other fatty materials and normally require no additives. Fire resistant hydraulic fluids of certain types are also used without additives. Most, but not all, petroleum-based lubricants do contain additives.

3.3 Toxic Substances

Before an attempt is made to classify lubricants and their additives as toxic or nontoxic substances, it is necessary to clarify the meaning of the term "toxic." Substances may be harmless or even beneficial to man and yet be hazardous to fish and other marine life. Other substances may be harmful when they enter the body via the respiratory system but harmless when taken in via the gastrointestinal tract. Some materials produce acute effects that disappear completely when the exposure ceases, while the effects of exposure to other materials may require many years to become evident. For purposes of this discussion, substances are classified as toxic whenever they meet any of the criteria for defining toxicity used by EPA, the National Institute for Occupational Safety and Health (OSHA), the Food and Drug Administration and other agencies. The most useful criteria are those used by EPA for designating hazardous air pollutants,[8] the OSHA list of cancer-suspect materials,[9] the EPA list of 306 materials that may be hazardous in natural waters,[10] and the list of substances permitted for use as foods, food additives, drugs, cosmetics or packaging materials according to the federal Food, Drug and Cosmetic Act.[11]

3.3.1 Toxicities of Lubricant Base Oils

Most lubricants used in steel mills are petroleum-based and present the same toxicological problems as petroleum-based materials used for other purposes. (The toxicities of additives are discussed in the next section). Extensive investigations have been conducted on these materials because of their widespread use, and until recently, they were classified as nontoxic. However, benzene which is a minor component of petroleum, has now been placed on the EPA list of hazardous air pollutants. Benzene is a low boiling material which is present primarily in gasoline and is almost entirely absent from the higher boiler lubricating oils. It is conceivable that traces of benzene might be associated with cut-back gear lubricants. Petroleum-based lubricants are troublesome in the water supply because they form oil films that are not pleasing aesthetically and have adverse effects on fish and water fowl. When lubricating oils are burned or otherwise subjected to very high temperatures, they may emit polynuclear organic compounds such as benz-α-pyrene that are known to be carcinogens. This phenomenon has been demonstrated many times in studies on oil-fired boilers and similar combustion processes. In the iron and steel industry, lubricants may encounter high temperatures at the sinter plant and during heavy duty applications. It is conceivable that polynuclear organics could be emitted at these locations.

In this discussion we must also consider the non-petroleum based lubricants. Vegetable oils and tallow are used in large quantities as process oils in the steel industry. These materials are found in natural meat and vegetable foods and present no hazards to humans nor are they listed as hazards in natural waters. They form oil films when discharged into wastewater with the same adverse effects as oil films from petroleum products. Glycols that are used in fire resistant hydraulic fluids do not present any special problems of toxicity. These same materials are used in much larger quantities for other applications -- anti-freeze, for example -- and do not require any special investigation in conjunction with their use in the steel industry. The toxicities of phosphate esters that are used as fire resistant hydraulic fluids are somewhat uncertain. Phosphate esters are not specifically included on any of the lists of toxic substances, but several other phosphorus-containing compounds are included. Further investigation might be appropriate to determine whether phosphate esters have ever been subjected to toxicological investigation and found to be harmless or whether they have never been tested at all. Fortunately, they are used in small quantities in steel making because of their high cost.

3.3.2 Toxicities of Lubricant Additives

None of the materials commonly used as lubricant additives are specifically included on any list of toxic substances; however, this does not mean that they have all been tested and found harmless. Many additives are unusual compounds that have no other uses and may never have come under scrutiny because of their proprietary nature. Presumably they will be included in the inventory of chemical substances which is currently being compiled to meet the requirements of the Toxic Substances Control Act, and, conceivably, some of them could be designated as high-priority test candidates.

The following list gives lubricant additives, in the approximate order of usage in a typical steel mill, along with comments about their possible toxicity. Quantitative estimates of usages and the ultimate fates of these additives are discussed later in Section 9.

1. Lithium-12-hydroxy stearate - Lithium compounds are not generally considered toxic nor are stearic acid derivatives. There is no reason to assume that this particular compound is toxic.
2. Molybdenum disulfide - This material has low volatility and is insoluble in water. According to the Merck Index "limited data suggest a low order of (human) toxicity."

3. Zinc dialkyl dithiophosphate - Many zinc compounds are biologically active and are used as fungicides, antiseptics and astringents. Dialkyl dithiophosphates do not appear to have been tested, or if they have been, the results were not published. This material probably should be investigated further.

4. Sulfurized and Phosphorized fatty oils - These are proprietary materials of uncertain composition. The parent fatty oils are not toxic, but it is uncertain whether any toxic properties result from the sulfurizing and phosphorizing treatments.

5. BHT (2,6-di-t-butyl-4-methyl phenol) - This material is approved for use as an antioxidant in food products and is non-toxic to humans.

6. Lead naphthenate - Lead compounds are generally classified as poisonous and naphthenic acid derivatives are considered hazardous. Fortunately this additive is being phased out, but it is unquestionably a toxic material.

A recent publication[12] has called attention to the presence of a toxic nitrosamine in synthetic cutting fluids that contain triethanolamine. Cutting fluids of this type are not used in steel mills according to the information collected for this study, so these toxic nitrosamines are not a problem in the steel industry.

Polychlorinated biphenyls (PCB) have been reported in fire resistant hydraulic fluids that are sent by Republic Steel to a reclaimer (Radco Industries). These materials are known to be toxic and are being phased out of all industrial usage. PCBs are not used as lubricants nor are they purchased by the lubrication departments of steel mills. They may be used in electrical transformers or other specialized equipment found at steel mills, but they should not contaminate lubricants except as a result of infrequent accidental incidents.

3.4 Purchasing Practices

The lubricant purchasing practices followed by the steel mills surveyed are described in this section. Two different practices or policies are generally followed with either reported to function satisfactorily. Many steel mills "buy by requirement," whereby the lubrication department selects lubricants and hydraulic fluids which meet the requirements specified by the equipment manufacturer in the warranty. In some cases the properties and characteristics are specified; in other cases a lubricant may be identified specifically by trade name. The lubrication staff is responsible to see that the correct product is selected, purchased and applied properly. The actual purchasing of lubricants and hydraulic fluids is done by the purchasing department. Application of the lubricants is typically done by the plant operators or maintenance department.

The second common method could be called the "buy by specification" practice. The lubrication department prepares and periodically updates, to reflect more stringent or changing requirements, a detailed lubricant "specification." These specifications reflect the equipment requirements and any additional or modified requirements determined from operating, maintenance and lubrication experience and performance. A complete set of specifications for a single steel mill may include two to four page "spec sheets" for over 100 oils, greases and hydraulic fluids. Every year or two the steel mill (via the purchase department and lubrication staff) requests competitive bids for the anticipated quantities of lubricants. Lubricant suppliers may offer an "off-the-shelf" product or a special product formulated for that particular steel mill. This lubricant purchasing practice can involve a major effort by the lubrication staff. One steel mill surveyed by PES purchases 120 different oils, greases and hydraulic fluids from more than 20 different lubricant distributors or manufacturers. As is the case in the previously described purchasing method, actual equipment lubrication is performed by the plant operators or maintenance department.

4. LUBRICATION SYSTEMS AND PRACTICES

The lubrication of operating equipment is an important factor in maintaining production, reducing delays and down-time, and lowering maintenance costs. To ensure proper lubrication, the steel industry has almost universally established lubrication departments to design, coordinate and review the lubrication systems and practices. In this chapter the responsibilities of the lubrication engineer, lubrication schedules, and lubricant application methods and systems are described.

4.1 Lubrication Requirements and Schedules

To effect proper lubrication each steel mill has a plant lubrication program. This program is normally coordinated on a plant-wide basis with each division keeping its own records and reporting to the plant lubrication engineer. Certain factors are inherent in every successful plant lubrication program. Briefly they are:

1. lubrication surveys
2. classification of lubricants
3. compiling and updating lubrication charts and consumption reports
4. improving application methods
5. lubricant handling and storage
6. evaluation of new products
7. establishing and running a maintenance program

4.1.1 Lubrication Surveys

A lubrication survey is designed to gather detailed information on current lubrication practices from the entire plant. The information gathered includes the type of lubricant, the part lubricated, and the frequency of lubrication. The lubrication engineer can determine the location and number of lubrication points, method of lubrication, and maintenance responsibility from an inspection of operating equipment. Operating personnel are questioned about each unit. If special or abnormal situations exist the equipment is inspected. A standard form is used to document all data and at times is posted or distributed to personnel as lubrication instructions.

4.1.2 Classification of lubricants

Lubricants are most easily classified under a basic performance classification. By assigning a requirement number to each class of lubricant, a descriptive means of identifying the lubricant is established. Each requirement number has a common identification which describes the general class of lubricant. In addition, the general characteristics of the lubricant class are made for each requirement number. The requirement numbers are sufficiently extensive to cover all lubricants applied throughout a plant. The classification of lubricants by requirement numbers enables the lubricant engineer to readily identify duplication of brand name products and assists in establishing a consolidated program. It simplifies the problems of procurement, storage, handling and application of lubricants.

4.1.3 Compiling and Updating Lubrication Charts and Consumption Reports

After the plant-wide lubrication survey data is compiled, it is normally transcribed onto punch cards. This is an efficient control method to effect proper inspection, lubrication frequency, quantity, and type of lubricant. All the data pertinent to inspection and lubrication is recorded on a master control card for each piece of equipment and component. The cards are distributed in accordance with the determined chronological frequency to the specified work area. Simultaneously, printed summary sheets of all the work performed are issued to supervisors. A master card is made up for each piece of equipment and each component part. It contains all of the information needed to identify, locate, inspect, and service a piece of equipment. The information is transferred from the master card to punch cards. The master cards can then be filed away for reference. Typical data entered on the punch cards are:

1. type of equipment
2. type of mechanism
3. lube trade name
4. quantity of lube per change
5. frequency of lube or inspection
6. quarter to schedule inspection
7. month of scheduled quarter
8. department responsible for lube
9. equipment number
10. total number of equipment
11. total number of mechanisms
12. number of lube points
13. frequency of lube change
14. building number

When the plant survey is concluded and all information has been coded on punch cards, procurement schedules must be prepared covering all equipment in the plant. The information necessary to prepare these schedules may be taken from the master cards. An effort is made at all times to keep the number of lubricants within an operating unit to a minimum. In some instances compromises are required which may be more advantageous than attempting to use the exact lubricant indicated for each bearing or gear. With the installation of new application devices or change in lubricant type, the procurement schedules change. The ultimate goal is to have current schedules that indicate the lubricant inventory and alternatives for the plant.

Since each plant spends a substantial amount of money each year on lubricants, consumption reports are necessary for recording and controlling the use of lubricating materials. Consumption reports are normally issued monthly in conjunction with an oil consumption budget. They help keep plant personnel aware of leakage and other problems.

Some oil generally escapes through shaft seals, but a number of conditions may develop which will cause excessive oil loss. Among these are cracked oil reservoirs, oil seal failures, excessive drain-off from settling tanks, and hidden breaks in pipe lines. As equipment grows older, oil loss increases. However, a good maintenance program can reduce the losses. Grease loss is less of a problem; therefore, controlling it is usually somewhat simpler. With grease, the chief loss takes place when timers on automatic centralized systems are set incorrectly. This automatically decreases when the correct lubrication frequency is set for the system.

4.1.4 Improved Application Methods

Since most of the present steel facilities were installed some time ago, and since capacities have increased through the addition of new operating units, older equipment represents a fertile field for lubricant savings through improved application methods. Additionally, older equipment is often inadequately designed from a lubrication standpoint.

Installing centralized systems on the older equipment reduces lubrication consumption and increases machine life. Some small machine tools, mobile equipment, wire rope, chains, etc. are still lubricated by hand, but they are changing to automatic and central-system lubrication. Localized lubrication still exists in steel mills, but only where it cannot be avoided.

4.1.5 Lubricant Handling and Storage

The large quantities of lubricants used in mill operations make storing and handling an important item from the standpoint of housekeeping, safety and costs. When lubricants are purchased in drums they are usually stored in a central area. Whenever possible, materials handling equipment is provided for the loading and unloading of lubricant containers. In central storage, drums are sorted to await collection by the supplier or a drum handling concern.

At the consumption site enclosures are provided for the drums and dispensing equipment. Covered containers are provided at every stage of handling to prevent contamination and maintain a clean and neat plant. To avoid error in use, each container is identified by requirement number, brand name, suppliers name, batch number, and other pertinent data as dictated by individual mill standards.

4.1.6 New Lubricant Evaluation

Once a lubricant has been chosen for a particular application, it is regularly evaluated against newer products. If a laboratory is available, the new product is tested; if the results are positive the new product is installed. There is a field trial period during which the lubricant's performance is recorded and compared to the former product. The comparison of lubricants for applicability, performance, and cost, provides a sound basis for choosing the product that will be used.

4.1.7 Establishing Maintenance Methods

From time to time, lubricant samples are tested in the plant laboratory. Oils in large circulating systems are especially susceptible to contaminants such as water, scale, coal dust, iron ore, metal particles and sludge. If tests show that the oil is reusable, particles are removed by one of three methods: settling, filtering, or centrifuging.

Settling lets the liquid stand in a tank allowing the contaminants to settle to the bottom. Filtering removes contaminants by pumping the dirty oil through paper, wood pulp, felt or clay filter material. Centrifuging spins the oil in a container forcing the contaminants upward and outward to a point where the water and dirt it carries are expelled. In many cases the oil may have degraded to a point where these methods are not suitable. In this situation the oil is replaced.

4.2 Lubrication Methods and Systems

Since steel is such an old industry, there are a variety of lubrication methods at any given mill. These include manual lubrication, old hand-operated mechanical devices, reservoirs, circulating and more modern central application systems. Before a decision can be made as to the most suitable lubrication method, an initial decision must be made as to whether the system requires oil or grease. Due to the basic differences between these lubricants, many choices are available when choosing an application system.

4.2.1 Oil Application Methods

There are four general categories of oil application methods, namely:

1. once-through oiling
2. oil reservoirs
3. circulating systems
4. methods for special equipment

There are various methods used in transferring oil from the drum to the actual lubrication points. A general procedure is to pump the oil from drum to supply can to lubrication system (hand oilers, pump oilers, reservoirs, and force feed systems). The oil is removed from the drum by hand, air-operated pump, or by gravity. Reservoirs of more than ten gallons are usually filled directly from the drum.

4.2.1.1 Once Through Oiling. Once-through oiling is so named because the oil passes through the bearing only once and is lost for further use. Methods of this type include hand oiling, drop-feed oiling, wick-feed oiling and bottle oiling.

Hand oiling is the direct application of oil to a moving machine part from a hand oil can. It is often used on older equipment. It is also used on newer equipment with small bearings involving little movement. One disadvantage of the method is that an excess amount of oil is applied which soon runs off, leaving the bearing to operate with insufficient oil until the next oiling.

When a more uniform supply of oil is required, a drop-feed oiler may be used. It consists of a shut-off lever, adjustment, oil chamber, needle valve, and sight glass.

The wick-feed oiler consists of an oil reservoir and a wool wick. The wick draws the oil from the reservoir and feeds it into an opening in the bearing. The amount of oil being delivered to the bearing can be regulated by changing the size of the wick.

The bottle oiler consists of an inverted glass bottle mounted above the bearing and fitted with a sliding pin which rests on the journal. When the journal rotates it vibrates the pin. The vibration initiates a flow of oil from the bottle to the bearing.

4.2.1.2 Oil Reservoirs. Reservoir methods use the same oil repeatedly, in contrast to the once-through methods. The oil supply is usually held in the base of a gear casing or bearing, but different methods are used to deliver the oil from the reservoir to the moving part, including ring oiling, chain oiling, oil collars, and splash oiling.

In the ring oiling method, a metallic ring, larger in diameter than the journal, rides on the journal and turns as the journal rotates. The ring, dipping into the oil, carries it to the top of the journal where it flows along and around the journal, providing lubrication before returning to the reservoir.

Chain oiling is similar to ring oiling except that a small-linked chain is substituted for the ring. The chain carries a larger volume of oil than the ring.

An oil collar may be used to carry oil from the reservoir to journals turning at high speeds. The collar, fastened to the journal, dips into the oil reservoir as the journal rotates, carrying the oil to an overhead scraper which removes and distributes it along the journal.

A group of bearings and gears enclosed in a single oil-tight casing usually employs splash oiling for lubrication. In this method, some moving part is in direct contact with the oil in the bottom of the casing. As the moving part turns, it splashes and carries the oil up to the other parts within the casing, keeping them well supplied with lubricant. Splash lubricating is the most reliable of all reservoir methods.

4.2.1.3 Circulating Oil Systems. Circulating oil systems make use of pumps and piping to deliver oil under pressure and often in large quantities to moving parts. Strainers are used for cleaning the oil and temperature control equipment is usually present to ensure constant viscosity. Many parts of rolling mills are usually equipped with circulating systems. The two primary types of circulating systems are the gravity feed system and the pressure type.

In the gravity feed system a pump draws the oil from a tank through a strainer to one of two overhead tanks. From there the oil flows by gravity through an oil cooler and then through pipes to the mechanism to be lubricated. From the mechanism it drains into the original tank from which it was pumped to repeat the cycle.

The pressure type of system is commonly used to lubricate heavy rolling-mill equipment. Oil flows over the gears and through the bearings into a settling tank. As the oil flows across the tank, the dirt and water tend to settle to the bottom. The oil is then drawn through a filter for additional cleaning. From the filter, the oil passes through an oil cooler and is delivered under pressure to the lubrication point. From here it is recycled back to the settling tank after use.

4.2.1.4 Methods for Special Equipment. The methods described so far are among those widely used in a steel plant. There are several other common oiling devices used on certain types of equipment. Wool waste or special felt pads are used for lubricating the track-wheel journal on cranes and railroad cars which are equipped with half bearings. In this method, wool waste is saturated with oil and packed into the space under and at the sides of the exposed journal, in direct contact with it. Oil is maintained in the journal box, and, as the journal turns, it is transferred to the journal and then to the bearing.

Another oiling method is the oil mist procedure. This method uses compressed air to atomize the oil from a reservoir and deliver it as a mist through pipes to the bearings and gears. This method provides an oil-saturated atmosphere, which lubricates the bearings while the air passing through, helps carry away heat as well as prevent dirt from entering.

In lubricating the piston and cylinder of a steam engine or large compressor a mechanical force feed lubricator is used. It consists of an oil reservoir and several pumping units that deliver oil in small amounts through pipes to the sides of the cylinders. Force-feed lubricators are also used for bearings and open gears where small amounts are needed.

4.2.2 Grease Application Methods

There are, basically, three methods of applying grease:

1. by hand;
2. by hand-operated mechanical devices, which deliver grease to one point of use at a time; and
3. by centralized grease systems, which supply a number of points of use from one central reservoir.

Grease is initially dispensed from the drum into an intermediate pump, except for reservoirs holding more than 34 kilograms (75 pounds), which receive it directly. A bucket pump may be used to fill lighter hand guns, or fill the reservoirs of small centralized systems. At times it is even fed directly to the fittings at the point of use. For a large number of bearings, a larger air-operated pump may be used.

4.2.2.1 Hand Application. Hand application is frequently used during the assembly of a machine. Grease is spread over gears and bearings to protect them from rust and ensure lubrication when the machine is started for the first time. In another hand method, melted grease is poured from a container onto gears or open guide bearings.

4.2.2.2 Mechanical Devices. Many types of mechanical applicators also require manual operation and refilling of grease. Grease cups, grease fittings, grease guns, bucket pumps, air-operated pumps, and spray guns are typical examples.

The grease cup is a familiar device for applying grease to bearings. The ordinary screw-down type consists of a small reservoir for holding the grease and a plate that screws down into the reservoir, exerting pressure on the grease and forcing it onto the bearing. It is filled by unscrewing the plate, filling the reservoir with grease, and replacing the plate.

Grease fittings have replaced grease cups on most steel mill equipment thereby making the use of pressure grease guns possible. Hydraulic fittings are used on most of the smaller machinery. Buttonhead fittings are used on heavier mill equipment where severe conditions exist and large volumes of grease are used.

Two types of hand-operated grease guns are commonly used. The lever gun is used primarily for greasing large pieces of machinery which use a large volume of grease, and are pressurized up to 69 megapascals (10,000 pounds per square inch). The push gun is generally used for delivering smaller quantities of grease at lower pressures.

A hand-operated bucket pump, holding about 15 kilograms (35 pounds) of grease, is used when a greater grease-holding capacity is desired. It may be used to fill hand guns through loader fittings or to pump grease directly into bearings through grease fittings. The bucket pump is operated by placing it on the floor and working the handle to deliver grease through a hose to the bearing. The bearing is usually equipped with a buttonhead fitting if it is to be lubricated with a bucket pump.

Air-operated grease pumps are used where a large number of bearings using a substantial volume of grease are to be lubricated. The pump, holding about 18 kilograms (40 pounds), is connected to compressed air and grease is delivered through a hose. At times barrel pumps are used which are inserted directly into a grease drum. These are used to apply grease directly to bearings, portable grease pumps or centralized systems.

Spray guns use compressed air to spray gear teeth with a film of grease. Grease is delivered to the spray gun through a hose from a barrel pump.

A centralized grease system is the best and most efficient way of lubricating a large number of bearings on a machine. These systems consist of a centrally located grease reservoir with a pump and piping that have grease distribution valves. When the pump is operated, each bearing receives a predetermined quantity of grease. The pump is usually operated by compressed air or an electric motor with a timer that stops and starts the pump at selected intervals. One of the several advantages of a centralized system is reduced leakage and losses and better housekeeping.

4.2.2.3 Centralized Lubrication Systems. A centralized lubrication system is a method of transmitting and measuring lubricant by means of a centralized pressure. The system assures a positive delivery of lubricant under adequate pressure to ensure the maintenance of a sufficient film between moving surfaces. The pressure is developed by a pump at the lubricant reservoir.

Two basic types of centralized systems are available: the parallel type and the series types. The primary difference between the two types is the location of the metering device in relation to the transmission line. Another difference is in the method used for returning the piston in the metering device to its original position. The parallel-system metering devices are off the main transmission line. The pump develops a predetermined pressure; individual counters are used at each metering device to indicate failure of the device to operate. There are two variations of the parallel type system; the single line and the dual line. The single line uses a relief valve to relieve line pressure and springs to return the piston for the next cycle of lubricant discharge. This system has one transmission line. The dual line has two transmission lines; they are connected such that pressure can be exerted on either end of the piston in the metering device. A "reverser" switches the pressure from one to the other, thereby accomplishing piston return and lubricant discharge.

The series-system metering devices are in the main transmission line. The pump develops the pressure necessary to overcome line and bearing resistance. Excessive pressure at the pump indicates the failure of the metering device to operate. There are two variations of the series-type system: the manifolded and the reversing. The manifolded type directs the lubricant flow through internal porting to accomplish piston return and lubricant discharge. Optional pressure indicators and relief fittings may be used on the manifolds. The reversing system employs a reverser to change the direction of lubricant flow.

5. WASTE OIL COLLECTION, RECLAMATION AND DISPOSAL

Oil in steel mill wastewater may be only a faintly discernible slick or a readily definable floating layer. The oily materials, resulting from the usage of various oils, greases and hydraulic fluids, may be chemically emulsified or mechanically dispersed producing various degrees of turbidity in the water. Some oily material may be adsorbed on floating solids, such as trash and debris, or be entrapped with solids which settle, such as mill scale. Waste oils and oily solids in wastewater may be very finely divided or even colloidal in size with little tendency to float to the surface or settle. The variety of types of oily materials found in steel mill wastewater, as well as the large wastewater volumes to be treated, make waste oil collection a difficult task. The chemical and physical properties of the wastewater itself greatly influence the design and operation of waste oil collection systems.

5.1 Types of Steel Mill Oily Wastes

Two general categories or types of oily wastes are present in steel mill wastewater streams. The first type, lubricants and cutting oils (mineral oils), can be subdivided into two classes: non-emulsifiable oils such as lubricating oils and greases, and emulsifiable oils such as soluble oils, rolling oils, cutting oils and drawing compounds. Emulsifiable oils typically contain fat, soap, or other additives to enhance their working properties. In general, the non-emulsifiable oils are separated with comparative ease. Emulsifiable oils, on the other hand, can cause considerable difficulty. Generally, the older the oil, or the more it is used in recirculating lubrication systems, the more difficult it is to separate. This is due to the slow oxidation of oils and greases with time and use, and as a result, the build-up of finely divided solids and metallic particles which are not completely filtered or centrifuged out during recycling.

The second type of oily waste present in steel mill wastewaters are fats and fatty oils. Tallows, palm oils and animal fats are generally used in cold rolling mills. These oils are basically triglycerides with various degrees of chemical unsaturation. They are more readily emulsified than the mineral oil wastes previously discussed in this subsection, and, accordingly, are more difficult to collect.

Used hydraulic fluids enter wastewater streams as a result of leaks. Their behavior in waste treatment systems is usually like those oily materials classified as lubricants.

Some additional understanding of the nature and source of oily wastes can be reached by considering briefly the steel mill processes or operations that generate major quantities of these wastes. Most oily materials in steel mill waste streams are from the various metal-working or steel-shaping operations. As described in Section 3 a wide variety of oil, greases and hydraulic fluids are utilized to help shape or form steel, cool equipment or the steel being worked, or to help operate the machines or mechanisms. The oily materials may be free or mechanically entrained in the wastewater and easily separated, or they may be bonded to solids or emulsified, to be removed only with difficulty.

Hot-mill effluent water generally contains mostly free or mechanically entrained oily material, some of which is bound to scale particles originating in the rolling operation. Flume water which has been used to cool the rolls and blow off scale contains some lubricating oils and hydraulic fluids. In cold strip rolling, the strip is usually oiled as it leaves the last wash after pickling. This reduces rusting and acts as a lubricant in the first-stand reduction. Emulsions of oils (rolling oils or soluble oils as they are often called) fats, tallows or palm oils are applied in subsequent reductions to cool the rolls and lubricate the strip and sometimes the roll bearings.

The rolling emulsion is often recirculated. The type of rolling fluid and its composition vary somewhat from mill to mill, depending on the type of mill and the product being made.

Other, generally lesser, sources of oily waste include the oils contained in rinse waters from cleaning operations used prior to plating or galvanizing, and cooling-water waste streams. The concentration of oils and greases is usually quite low in these waste streams, and the volume of water to be treated is often large, resulting in a difficult treatment problem.

5.2 The Waste Oil and Wastewater Treatment Problem

A basic principle of waste oil collection and steel mill wastewater management is to control or treat oily wastes as close to their source as practical. Generally, a small volume of concentrated oily waste is easier to handle than a large volume of diluted wastewater. In addition, early waste oil collection or control affords the best opportunity to segregate for reclamation as a usable product. The presence of a single contaminant or several contaminants in a waste stream may make another stream difficult to treat when the two are blended or may eliminate the possibility of recovering and reclaiming the waste oil in a usable form. The presence of emulsifiers, wetting agents, soaps, deflocculants, dispersants and finely divided suspended solids makes separation of oily materials from wastewater more difficult. If dilution and the introduction of these collection hindering materials can be avoided, the size of wastewater treatment equipment can often be greatly reduced. In addition, overall waste oil collection efficiencies can be improved.

Other factors which affect waste oil collectability are temperature and pH. Usually the higher the temperature of the oil waste, the easier it is to separate the oil from the water phase. Often the oily waste stream is at its highest temperature at its source.

The pH also influences waste oil collection. A high pH can hinder separation of oils while a low pH may be helpful or actually required for effective waste oil collection. The presence of acidic waste streams in steel mills is often used advantageously to enhance waste oil collection. On the other hand, indiscriminate blending of waste streams may produce an undesirable pH range for good oil separation. It may also increase the buffering capacity to the extent that pH adjustment to within the desired range would be impractical.

Collecting waste oils at their source also serves to simplify final steel mill wastewater treatment facilities and may allow for reductions in treatment facility size and costs. Waste oils recovered downstream in the wastewater treatment plant are usually contaminated and require more costly refining or processing before reuse. Recovery of the heat value of salvaged oil by burning as fuel should be used as a last resort. Air pollution problems may arise due to the presence of impurities in the oil if combusted. If the oily waste cannot be burned, ultimate disposal may be troublesome and costly. An additional reason for collecting waste oils at their source is that certain water treating chemicals can lead to oil and water separation problems.

Good housekeeping and maintenance can help minimize the waste oil load to be collected and reclaimed at steel mills. One of the major sources of oil wastes is carelessness in housekeeping and/or maintenance practices. Operators, in general, tend to use the most expedient approach to solving production problems often without regard to indirect factors such as wastewater contamination. The need and importance of finding and controlling leaks of oils and hydraulic fluids and containing and properly disposing of oil spills and oil soaked trash, must be emphasized by plant management. Regular inspections should be scheduled and/or leak detection devices installed to spot leaks. Corrective actions should be taken as soon as possible. A regular review of these housekeeping and leak prvention or control measures should be made for the purposes of updating, indoctrination and control. The more obvious leaks can usually be handled on a temporary basis, even if by nothing more than a bucket and an acceptable place to dump it. Emergency leak control measures should be undertaken until more permanent repairs can be made. Major repairs in the lubrication or hydraulic systems are usually delayed whenever possible, to coincide with a planned shut-down or turn-around. Good preventive maintenance goes a long way toward avoiding accidental and costly leaks and loss of lubricants and hydraulic fluids. The benefits of good housekeeping and maintenance are two fold. Excessive and costly lubricant and hydraulic fluid usage is avoided and the waste oil load on the wastewater treatment facilities is reduced.

5.3 Waste Oil Collection and Wastewater Treatment Equipment

A comprehensive description of all of the various oil-water separators and a discussion of separator design and sizing practices is beyond the scope of the PES study. The Manual on Disposal of Refinery Wastes Volume I, Waste Water Containing Oil, prepared by the American Petroleum Institute, provides an excellent description of oil-water separators and wastewater treatment equipment used for oil removal.[13] Included in the API manual are design nomographs and illustrations.

The functioning of most oil-water separators depends on the difference in gravity of the oil and water. The important factors affecting performance are the velocity of flow through the separator, settling time and separator design and maintenance. Floating oils are skimmed or drained from the surface of the separator. Several varieties or methods of skimming or oil removal are utilized. Gravity separators will not prevent the passage of emulsified oils; therefore emulsions must be broken if the oil is to be retained in the separator. Efficient methods for the resolution of emulsions should generally be determined by laboratory test and study prior to installation or application at steel mills. Emulsion breaking methods include chemical treatment, the application of heat and the use of alternating current. Acid addition, demulsifying chemicals and dehydrating chemicals sometimes are used to assist in emulsion breaking. Acid addition is commonly practiced at steel mills since spent pickle liquors are generally available.

Scale pits typically provide the first opportunity for oil separation. Older scale pits often do not provide adequate retention time or quiesence to achieve effective oil separation. Some type of oil skimmer must be installed and maintained to collect the floating oils. Although generally not the case, scale pits or separators should be constructed in two or more parallel channels so that continuity of operation may be maintained when individual channels are dredged, repaired, inspected or cleaned.

Separators of even the most modern design cannot be expected to perform efficiently unless given necessary attention of trained operators. Separators should be maintained as free of accumulated oil and sediment as possible, consistent with practical operating considerations. Often waste oils after collection, are fed into large barrels which if unattended, may overflow resulting in other oil clean-up problems. Excessive amounts of floating trash and debris if allowed to build up in scale pits or separators, will hamper waste oil collection. Cleaning and sediment or mill scale removal, should be undertaken when the flow of water through the scale pit or separator channel being cleaned is stopped. Mill scale, sediments and floating trash may contain or be coated with oil and should therefore be disposed of or stored in a manner which will not become a source of future surface-water contamination, such as during a heavy rain. The correct operation and maintenance of oil-water separators and waste oil collection equipment require responsible and regular attention of a trained operator.

As discussed previously in Section 5.2, the most effective waste oil collection practice is to capture the oil near its source or if possible, decrease the quantities of oil discharged or leaking from each source. Since this is not possible, and also because many of todays steel mills were designed and built prior to the current emphasis on waste oil recovery and pollution control, a variety of retrofit oil-water separation and waste oil collection systems are in use in the steel industry. Often oil skimmers have been retrofitted on to scale pits and operate by collecting floating oils and draining the captured oil into large barrels or waste oil storage bins. Brill or rope skimmers, a common type used in steel mill applications, consist of a long loop rope or tubing which floats on the scale pit or separator water surface. Floating oil clings to the rope which is hauled up continuously by motor and through a rope scraping mechanism. The collected oil is drained into barrels or bins which must be replaced or emptied periodically. Rope skimmers generally yield waste oil containing a relatively low percentage of water. Floating debris can become entangled in the rope causing damage to the rope or to skimmer itself. Thick oil or oily scum in scale pits, is sometimes difficult to collect with rope skimmers since the oil clinging to the rope must be lifted, often several feet, before scraping and collection.

Oil collecting pipes or troughs are also used on scale pits or oil-water separators. The trough or pipe with open slots for removing oil from the water surface is located at water level ahead of an oil-retention baffle. In the case of oil-collecting pipes, an operator periodically, upon inspection of the pit or separator, rotates the slotted pipe allowing floating oil to flow into the pipe and drain to a waste oil collecting basin or tank. If the water level exceeds the edge of the oil-collecting trough or if the oil-collecting pipe is rotated below the water surface, significant quantities of water will be collected with the waste oil.

A third method of waste oil collection from scale pits, separators, or retention ponds involves periodically drawing off floating oils with a vacuum truck. Typically this practice is employed when unusually large waste oil loads are experienced, during major leaks, spills or upset conditions. The collected waste oil often contains a large percentage of water which must be removed during reclamation.

Installation and operation of oil skimming or collection devices on scale pits is the primary approach to waste oil collection. Wherever quiescent conditions occur, oils will tend to separate and an opportunity for collection may arise. Collection of these floating oils reduces the oil load on any downstream control facilities. Water pollution discharge regulations have resulted in the addition of more sophisticated wastewater treatment facilities at domestic steel mills. Whereas waste oil collection for reclamation is often the objective of oil skimming, especially at scale pits or near the oil source, water pollution control (i.e., reducing the effluent oil/grease content, suspended solid content, concentration of toxic chemicals or pH control) is the goal for the wastewater treatment plant.

The combinations and types of wastewater treatment equipment installed at steel mills vary widely and were not extensively researched by PES. An effective treatment plant generally includes one or more of the following processes to reduce water pollutant discharge levels to acceptable levels. Emulsion breaking is necessary followed by collection of the oils which are freed. Chemical flocculation is commonly practiced to aid in trapping oil particles and removing them from the water by settling. This treatment is applied only after most of the oil has been removed from the water by gravity type separators. Disposal of the oily floc may constitute a difficult problem and effective flocculating chemicals may be expensive. Acid is often added to steel mill wastewater (pickling operations are generally the acid source) to aid in emulsion breaking. A properly designed and operated air-or gas-flotation unit also provides an effective means of removing oil from wastewater.

Flight skimmers are sometimes used at the head of wastewater treatment facilities if the oil load is high. A flight skimmer may consist of one or more channels in which flights (wood or metal cross members) are dragged by chain along the water surface scraping oily wastes toward the end of the separator where they are removed. This type of skimmer is effectively used where thick oil scums and foams are present at the water surface. Such scums are typically caused by animal fats or tallows in the wastewater from cold rolling mills. The handling of collected waste tallows, palm oils and fats is very messy and difficult since they often do not flow. Reclamation of animal fats and tallows from steel mill wastewaters is not generally practiced. Disposal of the collected fats, oily scum, etc. in a landfill is common, although other disposal methods are being sought.

A final opportunity for oil-water separation occurs in the final treatment lagoons or retention ponds. A vacuum truck or a floating skimming device can be used if appreciable quantities of oil accumulate.

5.4 Waste Oil Reclamation, Reuse and Disposal

There is a resurgence in the waste oil re-refining and reclamation industry, and an increased emphasis on waste oil collection at steel mills due to the increased cost of virgin oils, the desire to conserve valuable resources and the required reduction in environmental pollution. Frost and Sullivan,[14] in a recent marketing survey on waste lubricating oil re-refining, predict that the industry's annual growth rate from 1975 to 1985 will be 23 percent. By 1985, 60 percent of all waste oil available will be re-refined, up from the present level of 9.3 percent. New and improved reclamation and re-refining processes are being developed and the availability of companies providing such services to the steel industry is increasing.

Currently, there are about 35 re-refiners in the United States. It was not within the scope of this project to investigate and review all of the various re-refining processes. Two especially informative references, reviewed by PES and used as sources of background information for the project, are <u>Waste Oil Recovery and Disposal</u>[15] and <u>Industrial Oily Waste Control</u>.[16] The Association of Petroleum Re-refiners is another reliable source to be contacted for further information.

The PES study identified two basic types of waste oil reclaimers that handled steel mill waste oils. Waste lubricating oils (petroleum-based oils) collected by skimmers or drained from equipment and accumulated in waste oil containers are picked up by offsite, or, over-the-fence, waste oil reclaimers. These reclaimers generally collect and purchase all sorts of waste oil from industrial oils to crankcase oils. The second general type of reclaimer is typically located on-site and recovers rolling oils used on cold rolling or tin mills. Both lubricating oil reclaimers and rolling oil reclaimers are utilized by some steel mills, while other mills rely on only one type or neither type. A description of the waste oil recovery and reclamation efforts of the steel mills surveyed by PES is provided below.

PES surveyed American Recovery Company, Inc. (ARC), a major waste oil reprocessor. They have a plant in East Chicago, Indiana, that handles waste oils from three major steel mills in the Chicago/Gary region, and a plant near Sparrows Point, Maryland that processes waste oils from Bethlehem Steel. Typically, the waste oil collected at the steel mill contains about 60 percent water and miscellaneous impurities and 40 percent oil. According to an official at ARC, a very high recovery efficiency is attained in this reprocessing effort, with a loss of only about 0.2 percent.* From January 1 to September 30, 1976, the ARC facility in East Chicago received the following quantities of waste oil (including water) from the companies listed below:

*Personal communication with Loren Hoboy, General Manager, American Recovery Company, Inc. December 7, 1976.

Steel Mills	Waste Water and Oil*
United States Steel Corporation Gary, Indiana	9,055,780 l. (2,392,545 gal)
Inland Steel Company East Chicago, Indiana	4,624,630 l. (1,221,830 gal)
Youngstown Sheet and Tube East Chicago, Indiana	4,432,610 l. (1,171,100 gal)
TOTAL	18,113,020 l. (4,785,475 gal)

*About 7,245,200 liters of oil(1.914,190 gal)

Source: Letter from Joseph Krieger, Indiana State Board of Health, December 10, 1976.

The waste oil is normally reprocessed to fuel oil but an attempt is made, depending on the waste quality, to upgrade to a rolling, pickle or hydraulic oil. Most of the waste oil delivered to or collected by ARC is reclaimed as fuel oil. Inland Steel and Youngstown Sheet and Tube buy back quantities of fuel oil approximately equal to the quantity of waste oil sent to ARC. United States Steel at Gary does not purchase fuel oil from ARC. Recovered oils which are unsatisfactory for use as lubricants or fuel oil are often used as road oil.

At Kaiser Steel in Fontana, California, waste oil collected is picked up by an over-the-fence reclaimer and processed. The emphasis and desire by Kaiser is to have as much of the waste oil reclaimed as lubricant. As of mid-1977, approximately 76,000 liters (20,000 gal.) have been successively reclaimed as gear oil. The quantity of waste oil available for reclamation is about 568,000 l/yr (150,000 gal/yr). Waste oils not suitable for recovery as lubricant are reclaimed as fuel oil. Keeping the lubricating oils segregated from other waste liquids throughout the waste oil collection and recovery steps is essential to the success of reclaiming lubricants rather than fuel oil.

The recovery of rolling oils and fats is practiced at three of the mills surveyed by PES. PORI, Inc. was identified as the designer and operator of rolling oil recovery systems at several steel mills, including the Bethlehem Steel Sparrows Point facility and the Jones and Laughlin Aliquippa facility. Figure 5-1 illustrates the system installed at the Sparrows Point steel mill. Oily effluent from the cold sheet and tin mills is transferred by Bethlehem Steel by sewers to surge tanks located at the water treatment facility. Skimmed waste oils are transferred via pipeline by PORI to an adjacent waste oil refining facility. The waste oils are acid neutralized, vacuum filtered, washed and dried, and vacuum distilled. Refined, reclaimed oils are returned to the steel mill and used in pickling operations as rust preventatives and/or for cold rolling operations as rolling oil. The tin mill waste oils are segregated and processed separately from sheet mill waste oils on a batch basis. During 1976 approximately 18.5×10^6 liters (4.9×10^6 gallons) of waste oil (including entrained water) were processed by PORI at their Sparrows Point facility. The waste oils from the mills contain about 75 percent water. Of the 25 percent oil remaining, typically 5 percent are metals (primarily iron and iron soap) and 1 to 2 percent are dirt (solids). It was reported that 3.9×10^6 kg/yr (8.7×10^6 lb/yr) of oil were reclaimed by PORI in 1976 and of this, 2.2×10^6 kg (4.8×10^6 lb) of reclaimed oil were reused by Bethlehem Steel at the Sparrows Point facility. The remaining amount of reclaimed oil is marketed by PORI as fatty acids, fuel and rolling oils.

PORI, Inc. designs and builds waste oil recovery plants which are either operated for the steel mill by PORI or by the steel mill personnel. Nine PORI facilities at steel mills are identified in Table 5-1 along with annual capacities. The PORI facility recently installed at the Youngstown Sheet and Tube Campbell, Works is of particular interest since it:

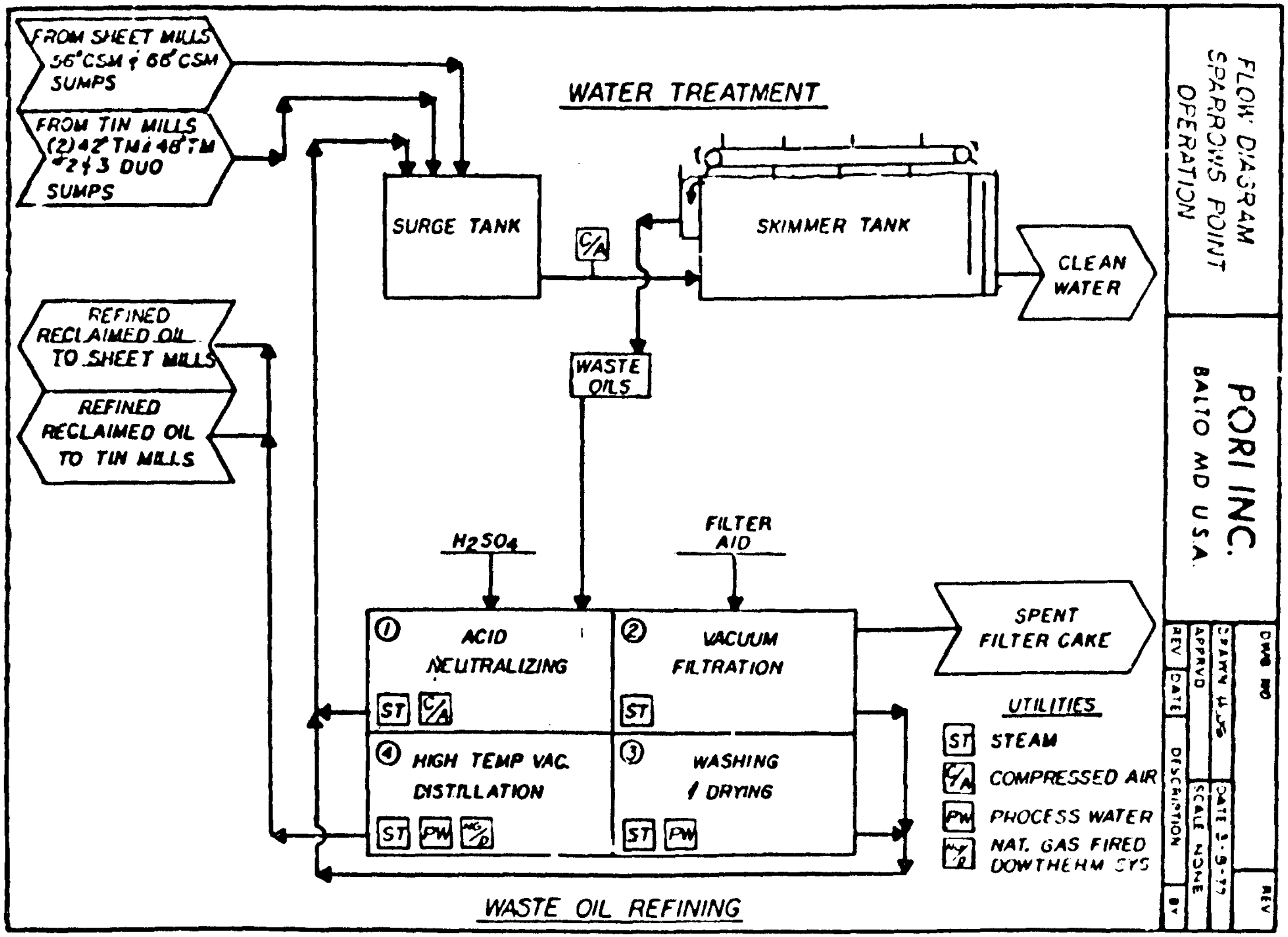


Figure 5-1. FLOW DIAGRAM SPARROWS POINT OPERATION

Table 5-1. PORI PLANTS

PLANTS BUILT AND OPERATED BY PORI

Steel Company	Year Built	Annual Capacity *
Bethlehem Steel		
Sparrows Point, MD.	1950	6,500,000 gals. Waste Oil
Burns Harbor, IN.	1972	3,500,000 gals. Waste Oil
Jones & Laughlin		
Aliquippa, PA	1953	1,000,000 gals. Waste Oil
National Steel		
Weirton, W. VA.	1963	6,500,000 gals. Waste Oil
Republic Steel		
Niles, OH.	1969	1,000,000 gals. Waste Oil
United States Steel		
Fairless Hills, PA.	1975	1,000,000 gals. Waste Oil

PLANTS BUILT BY PORI -- operated by Steel Company personnel

Steel Company	Year Built	Annual Capacity
Steel Company of Canada		
Hilton Works, ONT.	1973	6,500,000 gals. Waste Oil
National Steel		
Granite City, IL	1974	2,500,000 gals. Waste Oil
Youngstown Sheet & Tube		
Youngstown, OH.	1976	1,500,000 gals. Waste Oil

*Note: 3.785 liters = 1.0 gallon

1. produces clean water suitable for recycling and/or discharge;
2. refines all cold strip mill waste oil for either reuse or final disposal as fuel;
3. neutralizes acid rinse water.

The PORI facility at the Jones and Laughlin Aliquippa plant recovers rolling oil from the direct application tin mill. Recovered oil is returned to the pickling line, and is not reused as rolling oil. Reclaimed water from this PORI system is recirculated to the mill. Rolling oil from the cold strip mills at the Inland Steel Indiana Harbor Works is recovered by Bentex. No information on the Bentex facility was obtained.

Table 5-2 summarizes the utilization of waste oil recovery practices at the nine mills surveyed by PES.

In summary, it can be said that if waste oils are collected at their source and remain segregated from other oils and impurities, it is often possible to reclaim them in the form of a lubricant or motor oil. Currently, waste oils collected at many steel mills, are not segregated or are blended with other waste oils prior to reprocessing. As a result, most recovered waste oils are suitable only for use as fuel oils. Burning of recovered waste oils without sufficient removal of impurities, simply releases most of the contaminants into the air. Low quality reprocessed waste oil is sometimes sprayed or dripped on the coal fed to coke ovens for bulk density control. Other uses for the lower quality oils include road oils and dust suppressants. Sludges and oils not suitable for reuse must be disposed of in acceptable landfills. The use of oily sludges as an ingredient in asphalt was noted, but no details regarding this practice could be found and it is not known if steel mill waste oils are suitable for this purpose. The high metals content of steel mill sludge is reported to make them unsuitable for use in asphalt.

Table 5-2. REPORTED UTILIZATION OF WASTE OIL REFINERIES

Steel Mill and Location	Waste Oil Recovery Efforts	
	Lubricating Oils	Rolling Oil
United States Steel Corporation		
Gary, Indiana	Yes	No
South Chicago, Illinois	No	*
Inland Steel Company		
East Chicago, Indiana	Yes	Yes
Youngstown Sheet and Tube Company		
East Chicago, Indiana	Yes	No
Bethlehem Steel Corporation		
Sparrows Point, Maryland	Yes	Yes
Jones and Laughlin Steel Corporation		
Aliquippa, Pennsylvania	No	Yes
Republic Steel Corporation		
South Chicago, Illinois	No	*
Interlake, Inc.		
Riverdale, Illinois	No	No
Kaiser Steel Corporation		
Fontana, California	Yes	No

*United States Steel at South Chicago and Republic Steel do not operate cold rolling or tin mills and therefore do not use rolling oils or fats.

Discussions with the steel industry indicate that due to increased virgin oil and grease costs, and, to some extent, environmental regulations, more emphasis will be placed on collectin and recovering waste oils. Reclamation for lubricating or motor oils rather than fuel oil is more attractive if waste oil can be collected at their source and segregated from other wastes.

5.5 Discharge Rates

Various state water pollution control agencies were contacted and outfall data were requested for integrated steel mills. An attempt was made to determine typical oil and grease concentrations and mass discharge rates. Recent data are available for steel mills which have been brought under NPDES permit. NPDES permits generally require monitoring and reporting of several pollutants discharged from each outfall. PES obtained total oil and grease discharge data for various steel mills in Michigan, Ohio, Indiana, Illinois, West Virginia and Maryland. Several mills have not yet or have only recently begun to submit monthly or quarterly outfall reports. In several cases only concentration data is reported; in other mass discharge rates are reported. If the conduit or outfall flow rate and oil/grease concentration were both reported, PES calculated the corresponding mass discharge rate. It must be pointed out that total oil and grease sampling methods are generally considered to be subject to large errors due to difficulties in obtaining a representative sample (see Section 6.1). In addition, the data are reported on either a net or gross basis. The accuracy of mass discharge values calculated by multiplying a very high flow rate (typically in MGD and often estimated, not measured) and a low concentration (0 to 5 mg/l approaching the limit of detectability in the analysis method) is questionable.

A wide range of oil and grease discharge rates are reported from the various steel mills. Compliance with total oil and grease discharge regulations is maintained at nearly all of the steel mills for which data could be obtained. A few mills report zero discharge of oils having completed total wastewater recycling systems. The oil/grease concentration and mass discharge rate for a particular outfall at a given steel mill depends on the equipment discharging to that outfall and the waste oil collection and wastewater treatment equipment installed. Determination of the processes or equipment served by a given outfall, was attempted and is included with the outfall data. Tabulations of outfall data were made and brief summaries of the discharge data are provided in this section since detailed usage and process data could not be obtained for these mills. The vast differences in oil and grease discharges from mill to mill emphasize the need to consider each steel mill individually, recognizing the differences in process and equipment size and design and current waste oil collection and wastewater treatment practices.

5.5.1 National Steel Corporation - Great Lakes Steel Division

Outfall data for the National Steel Corporation, Great Lakes Steel Division, were obtained from the Michigan Department of Natural Resources. The Zug Island Plant in Ecorse, Michigan, consists primarily of coke ovens and blast furnaces. Eight outfalls serve this facility and the average total daily gross oil and grease discharge rate (from May 1975 to April 1976) was 2388 kg/day (5261 lb/day). The Ecorse Mill Plant, consisting primarily of rolling mills, is served by nine outfalls. During the same time period, 671 kg/day (1477 lb/day) of total oil and grease was reported on a net basis. One outfall serves the 80-inch hot strip mill and had a reported net daily average total oil and grease discharge rate of 4570 kg/day (10,070 lb/day). The hot strip mill wastewater contained an average of about 8 mg/l Freon extractable oil and grease. The Michigan Plant, an armor plate mill equipped with oil-water separators in the scale pits, discharges to a separate outfall. Only 1.4 kg/day (3.1 lb/day) net oil and grease was reported. If we consider these four sections or plants as an integrated steel mill, the total oil and grease discharge rate is approximately 7,672 kg/day (16,800 lb/day).

5.5.2 Ford Motor Company - Rouge Manufacturing Complex

Outfall data for the period April 21, 1975 to April 20, 1976 for the Ford Motor Company, Rouge Manufacturing Complex at Dearborn, Michigan, was obtained from the Michigan Department of Natural Resources. Four outfalls serve the plant which consists of coke ovens, a blast furnace, steel rolling and a foundry. The gross daily average total oil and grease discharge rate for the entire plant was reported to be 3430 kg/day (7553 lb/day). Nearly half of the total oil and grease discharge rate was from the outfall serving the rolling mills.

5.5.3 United States Steel Corporation - Lorain Works

U.S. Steel Corporation Operations in Lorain consists of several cold strip reducing and cold-finishing mills, a rod mill and a hot-strip mill. Data from the Ohio Environmental Protection Agency for the period June 1975 to April 1976, indicate that the average total oil and grease concentration in the wastewater discharged from the plant was about 5 mg/l. The daily outfall flowrate is 11×10^9 l/day (3,000 MGD) and the estimated mass discharge rate of oil and grease is 57,800 kg/day (127,500 lb/day).

5.5.4 National Steel Corporation - Weirton Steel Division

Region III of the EPA provided outfall data for the National Steel Corporation, Weirton Steel Division in West Virginia. The Weirton mill is integrated with over 300 coke ovens, 4 blast furnaces, 2 BOF's, 4 slab casters, a blooming mill, a structural mill, and several strip and sheet mills. The reported total plant oil and grease discharge rate for October 1975 through March 1976, was approximately 910 kg/day (2,000 lb/day). The average oil and grease concentration was 1.7 mg/l.

5.5.5 Bethlehem Steel Corporation - Sparrows Point Plant

The Maryland Department of Water Resources was contacted and visited to obtain NPDES outfall data for the Bethlehem Steel Corporation plant in Sparrows Point, Maryland. Total oil and grease discharge data is reported for three of the seventeen outfalls serving the steel mill. The NPDES permit limits the average and maximum total oil and grease discharge rate on two outfalls, and specifies limits on oil and grease concentrations for a third outfall. The two outfalls with mass discharge rate limits serve the hot forming, rod mill, wire mill, cold rolling, pickling and coating processes. From July 1975 to September 1976, the average daily total oil and grease discharge rate from these two outfalls was 3,560 kg/day (7,848 lb/day). In all but a few cases the reported mass discharge rate was below the average discharge level specified in the NPDES permit.

5.5.6 NEIC Data Summary

PES reviewed a set of reports which were prepared by the National Enforcement Investigations Center (NEIC) that contained oil and grease data on eight United States Steel Corporation plants in the Pittsburgh area. During the time that NEIC was conducting surveys of these plants most of them were not operating at their normal capacities and outfall flow rates were generally above the normal levels due to heavy rainfall. The oil and grease discharge data are briefly summarized in the following paragraphs. For a more detailed description of the NEIC report findings on oil and grease discharges, the reader should review the NEIC reports.[17]

The discharges were very high for the Edgar Thomson and Irvin plants. The reasons for these high discharge rates could not be determined from the reports, although both plants are very old. U.S. Steel has plans to construct new wastewater facilities at the Edgar Thomson and Irvin plants. The total daily average oil and grease discharges from various U.S. Steel plants are given in Table 5-3.

Since most of the oil and grease usage in an iron and steel complex is in the steel mill section, it would be expected that most of the oil and grease discharge would be from the fabricating mills. Oil and grease discharges from basic iron and steel production would not be expected to be very high. But this does not appear to be the case, as shown on Table 5-3. In the Edgar Thomson and Duquesne plants, which are basically iron and steel production plants with very little fabrication, the oil and grease discharges are very high. The reason for this could not be determined from the NEIC reports, although both plants are very old and lack adequate oil and grease removal and wastewater treatment facilities.

5.5.7 Outfall Data Summary

Several difficulties were encountered in trying to obtain outfall data which could be used for making comparisons about oil and grease discharge rates from steel mills. In many cases, the steel mills are not yet reporting outfall data because the NPDES permit has not yet been issued, is still in adjudication, or is being contested by the steel mill. Only steel mills which have been under permit for six months or more were potential data sources. Currently the only outfalls for which oil and grease data are measured and reported are those which are suspected of potentially significant oil and grease

Table 5-3. NEIC OIL AND GREASE DISCHARGE DATA SUMMARY

Plant Name	Net/Gross	Total Daily Average Discharge Of Oil and Grease Kg	Lb
Edgar Thomson Plant	Gross	9,012	19,872
Irvin Plant	Gross	8,556	18,823
Homestead Carrie Furnaces Plant	Net	122	345
Homestead Main Works	Net	634	1,395
Homestead Wheel and Axle Plant	Not Known	67	149
Duquesne Plant	Gross	1,440	2,770

Total daily average discharge data for the Clairton and National Plants were not reported in the NEIC reports.

discharges. Only oil and grease concentration data are reported in several cases, making it impossible to estimate mass discharge rates without the corresponding outfall flow rate. In some cases, the measured concentration and flow rate data are used to calculate mass discharge rates, and only the computed mass discharge rate is reported.

Daily average total oil and grease discharge rates have been presented in the previous subsections. Total oil and grease concentrations are measured by Freon extraction methods discussed in Section 6. Generally, grab samples are taken from one to five times per month. Flow rate data is typically estimated and reported as constant for a given month. Average and maximum oil and grease concentrations or discharge rates are reported to either the EPA Regional office or state pollution control agency if authority to issue NPDES permits has been delegated. Data is reported on monthly "discharge monitoring report" forms, often submitted at quarterly intervals.

As an example of a typical data request, the Indiana Board of Health, Division of Water Pollution Control, was contacted to obtain outfall data for oil and grease discharges from the three steel mills in that State which were included in the PES questionnaire survey. It was learned that outfall data for United States Steel at Gary was not available for use by PES. Only concentration data was available for Inland Steel and Youngstown Sheet and Tube, both in East Chicago. For these two mills, all outfalls were reporting from 0 to 5 mg/l.

A wide range of discharge rates is reported, differing greatly due to plant size, age design, the processes served by the outfall, plant maintenance and lubrication practices, and wastewater treatment methods. NPDES permits typically require the average oil and grease concentration for an outfall to be less than 15 mg/l and the maximum concentration per month to not exceed 30 mg/l. In some cases, the average and maximum outfall flow rate is combined with the 15 and 30 mg/l concentration limits and the permit limits are stated in terms of mass discharge rates. Currently, some states have qualified to issue NPDES permits and NPDES permits for the remaining states are being issued by the EPA.

6. WASTEWATER SAMPLING AND ANALYSIS

PES investigated and reviewed the sampling and analysis methods used for determining the oil and grease content of wastewaters for two reasons: (1) to appreciate the accuracy and representativeness of reported outfall data, and (2) to perform a sampling and analysis program if necessary, to obtain data for the PES study. Permission and arrangements could not be obtained to conduct scale pit and wastewater sampling at any of the nine steel mills surveyed, but the investigation of sampling and analysis methods did provide insight into the problems encountered in developing material balances for lubricants with discharge rate data. A summary and discussion of sampling techniques, and analysis methods for detection of oil and grease in water, are presented in this section of the report.

6.1 Sampling Wastewaters for Oil and Grease

The following three requirements are necessary for obtaining good results from any sampling program:

1. insuring that truly representative samples are taken;
2. using proper and reproducible sampling techniques; and
3. protecting and preserving the samples until they are analyzed.

The first of these requirements, obtaining a representative sample of the wastestream, may be the source of significant errors, especially in the case of grab samples. Total oil and grease determinations for steel mill wastewater generally involve periodic and infrequent (three to five times per month) grab samples to be taken manually. Waste flows can vary widely, both in magnitude and composition, during each day, and within a given wastestream at any time, the composition can vary due to partial settling of suspended solids or the floating of light materials, especially oil. Materials tend to deposit or collect in areas of quiescence or low velocities, such as near the walls of the flow channel. To minimize errors resulting from these factors, samples should be taken from the wastestream where the flow is well mixed. Often suitable sampling points are difficult to locate or gain access to. If mass discharge rates are of interest, flow measurements are needed. These must also be taken with care to ensure representativeness.

Composite sampling is impractical for oil and grease analyses. Samples must be analyzed separately because grease and oil losses will occur on sampling equipment and containers if compositing is attempted. A grab sample, usually a manually collected single portion of the wastewater, shows only the concentration of the constituents in the water at the time the sample was taken. The more variable the flow and composition of the wastestream, or the less frequent the sampling, the lower the probability is that the grab sample will be representative of the average wastestream conditions. Since composite samples are impractical, and continuous sampling would be too costly, iron and steel mills, are generally required (under the NPDES permit system) to take periodic grab samples from wastewaters for oil and grease analyses.

The methods of analysis for oil and grease in wastewaters (see Section 6.2) require a sample volume of approximately one liter (or one quart). Sampling containers must be glass and thoroughly cleaned before use. Wide-mouth glass bottles are typically mounted in a weighted cage or bucket which is lowered rapidly into the wastestream. The weighted sample bottle sinks rapidly, collecting a sample from the wastestream at various depths. Since oils and greases tend to float in quiescent wastewaters, samples should be collected in well-mixed turbulent locations, utilizing a rapidly sinking sample bottle to ensure that the entire sample does not consist of water from the surface of the wastestream.

Once a sample is collected, it should be marked or tagged for future identification. Since several plant and wastestream parameters influence the oil and grease concentration, data related to the production level, occurrence of oil leaks and spills, wastewater flow rate, sample location and time are important. In practice, much of this information is unavailable or otherwise not noted. It is desirable to run all analytical procedures immediately after sample collection. If samples are to be held for more than a few hours, they should be preserved by adding 5 ml of H_2SO_4 to lower the pH below 2.

NPDES data is typically reported on either a gross or net basis. If intake waters are sampled for oil and grease content, the net oil and grease concentration of outfalls can be determined. When interpreting or reviewing wastewater data, attention must be paid to the basis on which it is reported.

6.2 Analysis for Oil and Grease

The methods used for a total oil and grease analysis of wastewaters are specified in EPA's Methods for Chemical Analysis of Water and Wastes.[18] Three different techniques, all utilizing Freon 113 as a reagent to extract oils and greases, are used, although one of the methods is not well suited for steel mill wastewater oil and grease analysis. The two methods commonly used for the measurement of Freon-extractable matter from wastewater are capable of detecting total oil and grease concentrations in the range from 5 to 1000 mg/l. Complete copies of these two methods, Storet Nos. 00550 and 00556, are included for reference in Appendix B.

The Soxhlet Extraction Method (Storet No. 00500) involves filtering the sample which has been acidified to a low pH (<2) to remove the oils and greases from solution. Soxhlet extractors are used with

Freon, the extract is evaporated and the residue is weighed. Tests to determine the precision and accuracy of this method were performed. When one-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 88 percent, with a standard deviation of 1.1 mg.

The Separatory Funnel Extraction Method (Storet No. 00556) also begins with a one-liter, acidified (pH 2) sample. The sample is serially extracted with Freon in a separatory funnel. The solvent is evaporated from the extract and the residue is weighed. As with the previous test method, tests to determine the precision and accuracy of this method were investigated. When one-liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 93 percent with a standard deviation of 0.9 mg.

Both methods are influenced by the presence of extractable non-oily matter which may affect the material measured and the interpretation of results. As indicated by the precision and accuracy tests, not all of the oil or grease is extracted and detected. No data concerning tests performed with industrial wastewater samples dosed with typical lubricating oils and greases, hydraulic fluids, or rolling oils and fats was available in the literature. The precision and recovery of either of these test methods, in steel mill wastewaters, has not been investigated to date.

There are several devices available for monitoring oil and grease in wastewater, but they were not currently being used by any of the steel mills that were visited or contacted in this study. Since permit systems do not require continuous monitoring, periodic grab sampling is conducted once per week, which is less costly. Portable analyzers and continuous monitoring devices that operate on a variety of principles, are currently being marketed. These devices have not been installed or operated on steel mill outfalls, so no discussion of their usefulness is presented. Portable monitors are now available for sampling and analysis of oil and grease contents of wastewaters.

7. DATA GATHERING

This section contains a description of the data gathering methodology developed and performed by PES. The problems encountered and measures necessary to overcome these problems are discussed. The technical consultants providing input to the project are introduced.

7.1 Questionnaire Preparation and Survey Design

To obtain sufficient data to identify and quantify the use and fate of oils, greases and hydraulic fluids in the iron and steel industry, PES prepared a questionnaire and planned a survey. During the initial phase of the project, a literature review, the types of data needed and a project approach or methodology were identified. Since much of the data in the literature was not current and very little information related to lubricant usage and corresponding waste oil discharge rates and recovery or disposal practices were available, it was necessary to plan and execute an iron and steel mill survey. Time and project resource constraints, in addition to Office of Management and Budget (OMB) regulations limiting the number of questionnaires that can be sent out, fixed the survey sample size at nine.

A copy of the "Iron and Steel Mill Lubrication Questionnaire" developed by PES is presented on the next page. A great deal of data and information were requested, and a high degree of detail was solicited. Since the questionnaire dealt with two major areas (1) lubricant and hydraulic fluid selection and usage, and (2) waste oil recovery, wastewater treatment and discharge rates, it was expected that both lubrication and environmental personnel would respond to the questionnaire. Although it was expected that few of the steel mills could or would provide as detailed and complete a response as was requested by PES, it was anticipated that by including nine mills in the survey, adequate data for achievement of the project goals would be obtained for the industry in general.

IRON AND STEEL MILL LUBRICATION QUESTIONNAIRE

Instructions:

Please provide the following information in as much detail and as accurately as possible.

List all lubricants, oils, greases and hydraulic fluids used in the steel mill by trade name and supplier.

Specify where and on which equipment the above is used. (Include material balances if available.)

Specify quantities used and where.

Include any in-house specifications used in ordering lubricants.

Give a description of lubrication program including practices, schedules, methods and types of systems used. (Include schematics.)

Supply a general flowsheet identifying the waste water collection and treatment system including:

1. Amount of oil and grease treated
2. Collection efficiencies
3. Effluent discharge rates and sources
4. Methods of control
5. Amount reused or recovered
6. Other means of disposal of old lubricants
7. Description of sampling program
8. Total waste water flow
9. Modifications or additions planned for system

Preliminary research into steel mill lubricant usage, indicated that the most significant oil and grease using plant areas or equipment were the primary and secondary forming and rolling mills. By definition, the project was to investigate integrated steel mills. The emphasis was placed on larger steel mills with several forming and rolling mills because it was expected that they would be more likely to have extensive environmental and lubrication departments and therefore better data and records relevant to the PES study.

To identify candidate steel mills, information obtained during the literature review were utilized. The prime source of geographical plant size and descriptive information was Directory of Iron and Steel Works of the United States and Canada published by the American Iron and Steel Institute.[19] The nine steel mills listed in Table 7-1 were chosen for the survey. The plant location and total number of forming and rolling mills are also presented in the table.

Table 7-1. IRON AND STEEL MILLS SENT QUESTIONNAIRES

Region III		
Jones and Laughlin Steel Corp.	Aliquippa, Pa.	12 mills
Bethlehem Steel Corp.	Sparrows Point, Md.	27 mills
Region V		
Inland Steel Co.	East Chicago, Ind.	30 mills
Interlake Steel Co.	Riverdale, Ill.	16 mills
Republic Steel Co.	South Chicago, Ill.	7 mills
United States Steel Corp.	Gary, Ind.	31 mills
United States Steel Corp.	South Chicago, Ill.	10 mills
Youngstown Sheet and Tube Co.	East Chicago, Ind.	14 mills
Region IX		
Kaiser Steel Corp.	Fontana, Calif.	16 mills

7.2 Contacts and Responses

The process of obtaining data from the nine selected steel mills began with the identification of key personnel within each steel mill to mail the data request and coordinate response preparation. Telephone calls to the nine mills were made, in most cases, to the director or department head of the environmental control section. In each case PES and the EPA contract under which the project was funded were introduced and a brief description was provided of the nature of the study and types of data being sought. The name, title and address and telephone number of the steel mill personnel who would coordinate efforts to prepare the response to the questionnaire was noted. In most cases it was indicated by the steel mills that responses could be provided but PES had to make all data requests in writing.

Questionnaires with cover letters were mailed to the nine steel mills during June and July of 1976. The cover letters identified PES as an EPA-IERL contractor and provided a brief description of the project approach and the study objectives. It was expected that one or two months would be needed by the steel mills to prepare written responses. After approximately one month, follow-up telephone calls were made to the people who had been sent questionnaires to determine the expected completion date and resolve any questions which may have arisen. Several of the nine mills indicated that all requests for data including the PES questionnaire, had to be reviewed and approved by the legal department, plant management, or the corporate engineering office prior to being released to PES. It was also indicated that the questionnaire called for a great deal of information not immediately available or previously tabulated in the desired format. In nearly all cases, input to the questionnaire response was needed from the lubrication department, environmental department and plant maintenance or operating departments. Often purchase records had to be reviewed and tabulation of lubricant usage prepared especially for PES. (If relevant data were previously tabulated or summarized for in-house or other purposes, PES attempted to make use of such data thereby simplifying or reducing the demand on the industry's time.) Several other factors were cited which contributed to the delays and difficulties in preparing questionnaire responses. The steel mill contacts noted that the amount of information and data requested by PES required a significant expenditure of man-hours. Environmental and lubrication staff are very busy with other responsibilities. For example, air pollution regulations, particularly for coke oven emissions, have raised control problems that place major time and manpower demands on available staff. Pollution control equipment design, selection, start-up, operating and testing; studies of in-plant environmental problems; and other commitments to provide various agencies with emission and discharge data, keep steel mill environmental staffs very busy. Emission or discharge violations and other enforcement activities, at both the federal and state levels, have sensitized the steel industry. An attitude has developed that information provided to pollution control agencies or their contractors may be used against them at some later date. The research oriented role of IERL, and this project in particular, were emphasized and the desire to prepare an objective and comprehensive investigation were cited as reasons for surveying the industry for data.

Due to the amount of data requested and the factors discussed in the preceeding paragraph, completion dates in October or November (about three or four months from the time the PES questionnaires were mailed) were estimated by the nine steel mills. PES decided to recontact each of the mills periodically (once or twice per month) to ensure that the questionnaire had not been forgotten and to answer questions concerning the data request or project objectives. The importance of current industry data to the project called for efforts to keep in contact with the nine steel mills. The project schedule was modified to tolerate the data gathering delays and difficulties.

7.3 Plant Visits and Interviews

As the initial questionnaire responses were received, it became clear that the responses generally lacked the degree of detail desired for the project, particularly for developing material balance estimates for oils, greases, and hydraulic fluids. It was decided that an attempt would be made to visit each of the nine steel mills to inspect facilities and interview personnel knowledgeable in lubricant usage and application, waste oil recovery and reclamation, and wastewater treatment. Telephone calls followed by written requests for a plant visit were made to the steel mills.

Permission to visit and arrangements to discuss the PES project were finalized for six of the nine steel mills who were sent questionnaires. One day plant visits and appointments with environmental and lubrication department personnel in the following plants were scheduled during October and November of 1976 with the following plants:

United States Steel Corporation - Gary, Indiana
Inland Steel Company - East Chicago, Indiana
Interlake Steel Company - Riverdale, Illinois
Jones and Laughlin Steel Corporation - Aliquippa, Penna.
Bethlehem Steel Corporation - Sparrows Point, Maryland
Kaiser Steel Corporation - Fontana, California

The data provided in the initial written responses were discussed at the plant visits, and the steel making and shaping equipment, waste oil recovery practices, and wastewater treatment facilities were inspected. The scope and objectives of the project were reviewed and data availability discussed. If additional useful data was identified and determined to be available, a request for such data was made. Follow-up telephone calls were made after the visits to expedite these data inputs.

7.4 Second Data Gathering Efforts

Files of data, questionnaire responses, plant visit notes and telephone contact reports were prepared for each of the nine steel mills. Significant differences in the depth or degree of detail were noted between the nine mills surveyed. The information and data contained in these files were reviewed and used to prepare a preliminary data summary and material balance estimate for each steel mill. At this time it was decided that a second data gathering effort was needed to obtain additional data necessary for preparing more complete material balance estimates. The project was extended to allow additional time for recontacting the steel mills.

A list of questions for each of the mills was prepared to obtain more data. Eight of the steel mills were recontacted by telephone and notified that additional data and comments on the preliminary data summary and material balance estimate were being sought. United States Steel at South Chicago was deleted from further study because of difficulties in obtaining data, and the fact that a second United States Steel plant, the Gary Works, was included in the FES survey. The preliminary data summaries and material balance estimates, essentially the first draft of the individual steel mill data summaries presented in Section 8, were mailed to the respective steel mills. Again, telephone calls were made to expedite and discuss the additional data requests. The comments and additional data received from each of the mills was used to finalize the data summaries and material balance estimates and prepare the material in Section 8 of this report.

To supplement the steel mill data, a survey was made of waste oil reclaimers that handle waste oils from one or more of the mills under study. PES requested information relating to the quantity and nature of the steel mill waste oils processed and general information concerning waste oil reclamation practices. The data and information from waste oil reclamation companies is discussed in Section 5, as well as in Section 8, in conjunction with the appropriate steel mill data.

7.5 Consultants

To assist in the performance of the project and to provide additional sources of lubricant usage and fate information, consultants were contracted by PES. During the PES study two different areas were identified that required technical support and called for consultants with specialized backgrounds. At the outset of the project, technical support and a supplementary data source for the area concerning steel mill lubricant characteristics and usage was required. It was determined that a consultant with strong steel industry experience in lubrication engineering would be beneficial to the project. The American Iron and Steel Institute (AISI) was contacted to make recommendations or provide PES with a list of potential consultants. As a result of this consultant search, Joseph D. Lykins was contracted by PES. Mr. Lykins, assisted by Paul D. Metzger, contributed valuable lubricant usage date to the study. Messrs.

Lykins and Metzger are both recently retired from Wheeling-Pittsburgh Steel Corporation and are currently acting as private consultants to several iron and steel mills and lubricant distributors. Mr. Lykins served as the Corporate Lubrication Engineer for twenty-five years and Mr. Metzger was the Supervisor of Testing for the Lubrication Department. Both are long-term active members and have served on technical subcommittees of the American Society of Lubricating Engineers (ASLE), the American Society for Testing and Materials (ASTM), and the Association of Iron and Steel Engineers (AISE). Mr. Lykins provided PES with typical lubricant usage data. For fifteen types of lubricants the yearly consumption for an integrated steel mill producing three million net tons of steel annually was estimated. A detailed tabulation of lubricant types and quantities applied monthly for twelve major plant processes or areas was also prepared for the PES study. The types of bearings and gears, types of lubricants applied and monthly usage data were tabulated for the various parts or equipment within each mill or plant area. The input that was received from Mr. Lykins is summarized in Section 8. Additional data provided by Mr. Lykins is included in Appendix C as it contains a great deal of valuable information.

During the second data gathering effort, PES recognized the need for a second consultant with experience in the steel industry and a knowledge of the fates of steel mill lubricants. Again the AISI was contacted for consultant recommendations. Richard Jablin was selected by PES and contracted to provide information and assistance in the area of material balance estimation and the fate of steel mill lubricants. Formerly with the Bethlehem Steel Corporation and Alan Wood Steel Company, Mr. Jablin served in a number of positions including Plant Engineer, Manager of Engineering and Construction, Director of Environmental Control. Since 1975 he has been self employed as a consultant to the steel industry and has assisted in several EPA studies. He is a member of the Association of Iron and Steel Engineers (AISE), and is a past Chairman of the Steel Committee of the Air Pollution Control Association (APCA).

Mr. Jablin provided PES with a material balance estimate for an unidentified steel mill, "Mill A," and based on his knowledge of the industry and material balance data collected by PES, he prepared a material balance estimate for a "typical" steel mill. The input provided by Mr. Jablin is summarized in Section 8. A copy of Mr. Jablin's project input (without appendices) is provided in Appendix D.

8. DATA ANALYSIS AND MATERIAL BALANCES

A prime objective of the PES survey was to analyze data from the consultants and from the questionnaires completed by nine steel mills, and to use this information to develop material balance estimates identifying the usage and fate of lubricants, oils, greases and hydraulic fluids. As discussed in the previous chapter, it was a very difficult and time consuming task to obtain sufficient data. Several factors influence the quantities and types of oils, greases and hydraulic fluids that are used. The fate of these lubricants and hydraulic fluids is also affected by several parameters. Any comparison or analysis of data from different steel mills must include a description of these parameters. In this chapter the available data, methodology for data analysis and material balance estimates for steel mill oils, greases and hydraulic fluids is presented.

8.1 Factors Affecting Lubricant Usage and Fate

During the course of gathering data on and visiting the steel mills, several factors were identified which influence lubricant usage rates and the fates of these lubricants. These factors are discussed because it is important that the reader understands the limits of the data and the problems of the material balance development. As a result of these factors, potentially significant errors are encountered in attempts to combine data from different steel mills to make industry-wide generalizations. It should also be noted that, for the most part, the steel mills in the study were cooperative, and the delays or problems in gathering data were often the result of a lack of data within the steel mills. Generally, sufficient data to develop material balances for total or specific oils, greases and hydraulic fluids does not exist. Few, if any, mills have studied the problem in detail, although rising lubricant costs are stimulating interest in investigations of potential waste oil recovery schemes and quantities.

The most obvious factors influencing lubricant usage (and their fate), are the size, design and age of the steel mill equipment. A great variety of equipment and major differences in the age and production capacity exist in the American steel industry. The lubrication practices and application methods also vary quite widely. These factors, as well as maintenance and housekeeping practices, influence the amounts and types of lubricants applied and, to some extent, the fate of these lubricants. Also different amounts of a variety of steel products are produced at the various steel mills. Waste oil collection and reclamation efforts differ widely from one mill to the next. Currently, most steel mills are primarily trying to prevent excessive oil and grease discharge rates (as specified in NPDES permits). Other mills are engaged in programs aimed at recovery and reclamation of waste oil, as well as water pollution control. Differences in the steel mill organization schemes and management policies also influence waste oil recovery practices. The responsibilities of the lubrication, environmental, maintenance and operating departments vary at the different steel mills. The sensitivity or awareness of maintenance and operating personnel can affect the overall steel mill efforts to conserve and recover lubricants and hydraulic fluids.

8.2 Methodology for Data Analysis

A prime objective of the PES study was to develop material balances for oils, greases and hydraulic fluids used in the steel industry. In the process of gathering data and discussing the project with the steel industry, the terms of a general material balance were identified. As illustrated in Figure 8-1, two input terms, virgin make-up and reclaimed or recycled lubricants and hydraulic fluids

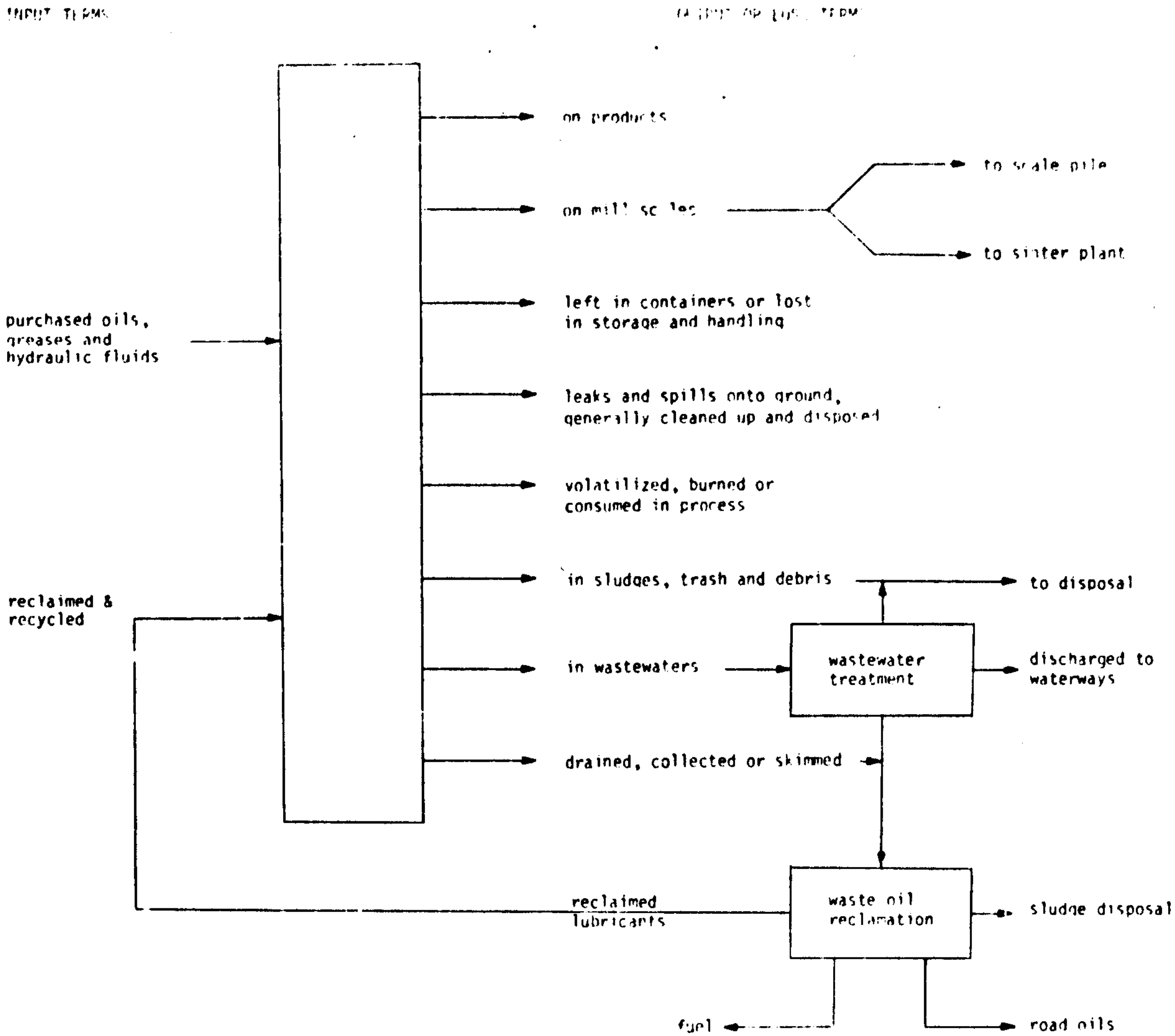


Figure 8-1. LUBRICANT, OIL, GREASE AND HYDRAULIC FLUID MATERIAL BALANCE ESTIMATE

enter the material balance. Several output or loss terms are identified in the figure, including: lubricant losses on the steel products shipped from the plant; oils and greases attached to mill scales which are stockpiled or recycled to the sinter plant; lubricants, especially greases, left in containers or lost during storage and handling; oils and greases on trash and debris that are collected and disposed of; leaks and spills to the ground or floor which are generally cleaned up and disposed of; lubricants volatilized, burned or consumed in various steel making and shaping processes; and oils, greases and hydraulic fluids in the wastewater streams which are either discharged to waterways or are recovered and disposed of or reclaimed. Oils, greases and hydraulic fluids are also collected, drained directly into either a waste-oil collection bin or tank, or recovered by oil skimmers, in scale pits and wastewater treatment facilities, and treated on or off-site in waste oil reclamation facilities for use as lubricants, fuels, or road oils. Reclaimed rolling oils are generally equal in quality to virgin rolling oils and can be recycled effectively. Reclaimed lubricating oils are generally of lower quality than virgin lubricating oils and are used as fuel or for less demanding lubrication applications. Oily sludges are generated from wastewater treatment facilities and waste oil reclamation systems.

Quantifying each of these input and loss terms for each oil, grease or hydraulic fluid was determined to be an impossible task. A given lubricant may be used in several areas or pieces of equipment and may appear in several wastewater circuits. The wastewaters from different areas of the plant are often combined, resulting in a blend of oils and greases which cannot be separated and traced to their sources. The wastewater sampling and analysis methods that are currently being used only determine the total quantity of oil and grease. No distinction is made between different oils, greases and hydraulic fluids. Several of the output or loss terms, although recognized by the steel industry, have not been investigated to date and quantitative data of any type is unavailable.

With the available data, it was decided that a single material balance estimate for the total oil, grease and hydraulic fluids input to the steel mills would be prepared. The questionnaire responses from the nine steel mills varied significantly in the degree of detail provided. It was not possible to estimate an overall material balance at all of the steel mills due to inadequate or incomplete data bases. In all cases, some of the material balance loss terms were estimated by PES based on subjective evidence. The percent of the input unaccounted for is reported for mills that do not have 'closed" material balances. The data, estimates and material balances for individual steel mills are presented in the remainder of this section. The data regarding lubricant usage and rates that the consultants provided is also presented.

8.3 United States Steel Corporation

8.3.1 Gary, Indiana

A summary of the major equipment and products associated with the United States Steel Corporation, Gary Works, is presented in Table 8-1. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief, the steel production capacity at the Gary Works is 7.3×10^9 kg/yr (8.0×10^6 tons/yr). The actual production rate was approximately 4.6×10^9 kg/yr (5.1×10^6 tons/yr) during the period for which lubricant usage data were reported.

TABLE 8-1

UNITED STATES STEEL CORPORATION - GARY, INDIANA*

Equipment

584 Coke ovens - by-product
11 Blast furnaces
2 Basic open hearth furnaces
6 Basic oxygen furnaces
1 Continuous caster 1 strand - slab

NO.	Type of Mill	Annual Rolling Capacity	
1	Slab	2,820,000	5,211,000 Net Tons
1	Billet	1,200,000	
2	Blooming	1,191,000	
1	Rail	682,000	15,557,800 Net Tons
1	Plate	574,000	
9	Bar	2,083,000	
2	Hot strip	6,010,000	
3	Sheet - Cold roll	1,314,800	
5	Sheet temper	2,365,900	
3	Tin-Cold roll	1,547,400	
3	Tin temper	980,700	
31		20,768,800	NET TONS

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} = \frac{12.2188 \times 10^6}{20.7688 \times 10^6} = .59^{**}$$

Notes
* Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works (1.0 ton = 907.2 kg).
** This parameter was computed for later use; correlating lubricant usage and product type. (See Sect 9.1.2).

8.3.1.1 Lubricant Purchases. Based on records of actual consumption for the first six months of 1976, the approximate amounts of lubricating oils, greases and hydraulic fluids are as follows:

Oils	568,000 l/month	(150,000 gal/month)
Greases	59,000 kg/month	(130,000 lb/month)
Hydraulic Fluids	76,000 l/month	(20,000 gal/month)

Assuming an average density of 0.90 kg/l (7.5 lb/gal) for lubricating oils and hydraulic fluids, the total input of oils, greases and hydraulic fluids was 7,650,000 kg/yr (16,860,000 lb/yr).

Lubricating oils used at the Gary Works are divided into 25 categories most of which are used in small volumes. The majority of the consumption of oil is accounted for by three categories: gear oil, which is used for lubricating bearings and gear drives; circulating oil, which is used for lubricating oil-film back-up roll bearings; and, circulating turbine oil, which lubricates the moving parts of turbines, machine tools and hydraulic machines by means of pressure circulating pumps.

Greases are similarly divided into 13 categories, with 3 categories accounting for the bulk of the consumption. These are: mill utility grease, a general purpose grease used throughout the plant for bearings and roll necks; high temperature grease, similar to the first category but designed for use in high temperature areas; and, extreme temperature grease, for still higher temperature applications.

The hydraulic fluids are divided into nine categories, with the bulk accounted for by two categories: soluble oils (actually mineral oils with emulsifiers added), used in general metal working conditions; and, noninhibited hydraulic oil for general use in hydraulic systems. A smaller contributor is phosphate ester fluids, used where fire hazards may be present.

8.3.1.2 Reclamation and Treatment. The oils described above are mainly consumed in mills which have scale pits, some of which are equipped to capture and remove floating oils. All the process waters from the primary mills and bar and structural mills receive additional final clarification and oil removal in the terminal lagoons. Process waters from the hot strip mills receive filtration in addition to primary treatment in scale pits. Process waters from the finishing mill are treated at the terminal treatment plant. There, free oil is removed by five API gravity oil separators operating in parallel. Soluble oil is removed by coagulation with waste pickle liquor and sedimentation in three flocculator-clarifiers.

American Recovery Company, Inc. (ARC) has been contracted by United States Steel Corporation to collect waste oil by truck from eleven collection tanks located at the Gary Works. Data obtained from the Indiana Board of Health indicate that approximately 12,074,150 l/yr (3,190,000 gal/yr) of waste oil (containing 60% H_2O) is collected by ARC from the Gary Works. It is estimated that of this quantity, 4,733,150 l/yr (1,250,500 gal/yr) of waste oil are reclaimed as fuel oil and 96,520 l/yr (25,500 gal/yr) of oily sludges are generated. The quantity of fuel oil reclaimed represents nearly 55 to 60 percent of the total oil, grease and hydraulic fluid input. About one percent of the total input is accounted for in the sludges from ARC.

8.3.1.3 Discharges to Waterways. NPDES data were not furnished for the Gary Works. The net oil and grease load discharged in wastewaters is estimated by U.S. Steel to be 45,360 kg/month (100,000 lb/month). The net, rather than gross, amount must be considered in computing material balances because the one or two parts per million oil present in the intake water, when multiplied by the volume, becomes a significant factor in the oil balance.

8.3.1.4 Other Losses. Oils and greases that are applied on products, intentionally for rust prevention, or that are picked up during rolling and finishing, are recognized as a significant material balance loss term. The quantity of oils and greases leaving the Gary Works on products is estimated by the company at 22,700 kg/month (50,000 lb/month).

Oils and greases on mill scales represent another significant material balance loss term. The oil content of mill scales from some rolling mill scale pits is reported to reach up to 25 percent by weight. As indicated in the material balance illustration, mill scales are generally either recycled to a sinter plant for recovery of the metal or stockpiled for future recovery due to air pollution control equipment or opacity problems caused by the oils volatized during sintering. At the Gary Works, mill scales are currently recycled. The larger chunks are returned directly to the blast furnace while the remaining scale is sent to the sinter plant. The volatized oils are reported to cause a bluish plume at some sinter plants. The slow moving sinter machine flame front volatizes rather than combusts the oils contained on the mill scale. The amount of oil contained in mill scale is estimated by the mill to be 6,800 kg/month (15,000 lb/month).

Sludges that are removed from wastewater treatment facilities at the Gary Works also contain oils and greases. The quantities of oil and grease in these sludges are reported to be about 181,000 kg/month (400,000 lb/month).

Other loss terms identified in the oil, grease and hydraulic fluid material balance, and for which estimates were provided by the steel mill, include the:

- amounts left in containers or lost during handling and storage, (estimated at 5,900 kg/month (13,000 lb/month));

- oils and greases contained on trash and debris which are collected and sent to a solid disposal area; (estimated at 4,540 kg/month (10,000 lb/month));
- quantities volatilized, burned or otherwise consumed in use in the various steel making and shaping processes, (estimated at 23,600 kg/month (52,000 lb/month));
- leaks and spills which are cleaned up and disposed of or leak into the ground, (estimated at 4,540 kg/month (10,000 lb/month)).

8.3.1.5 Material Balance. Using the data and estimates presented above, an attempt was made to develop an overall material balance for total oils, greases and hydraulic fluids. The material balance estimate is illustrated in Figure 8-2. For conversion of volume to weight units for oils, a density of 0.9 kg/l (7.5 lb/gal) was assumed. Shown on the material balance illustration are lb/month values for several terms and an estimate of the percent of the total input represented by each loss term. Note that no data was provided for process or rolling oils and consequently these materials are not included in the input term of the material balance estimate.

8.3.2 South Chicago, Illinois

A summary of the major equipment and products associated with the United States Steel Corporation - South Chicago Works is presented in Table 8-2. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief, the steel production capacity at the South Chicago Works is 4.76×10^9 kg/yr (5.25×10^6 tons/yr). The actual production rate was approximately 3.4×10^9 kg/yr (3.7×10^6 tons/yr) during the period for which lubricant usage data were reported.

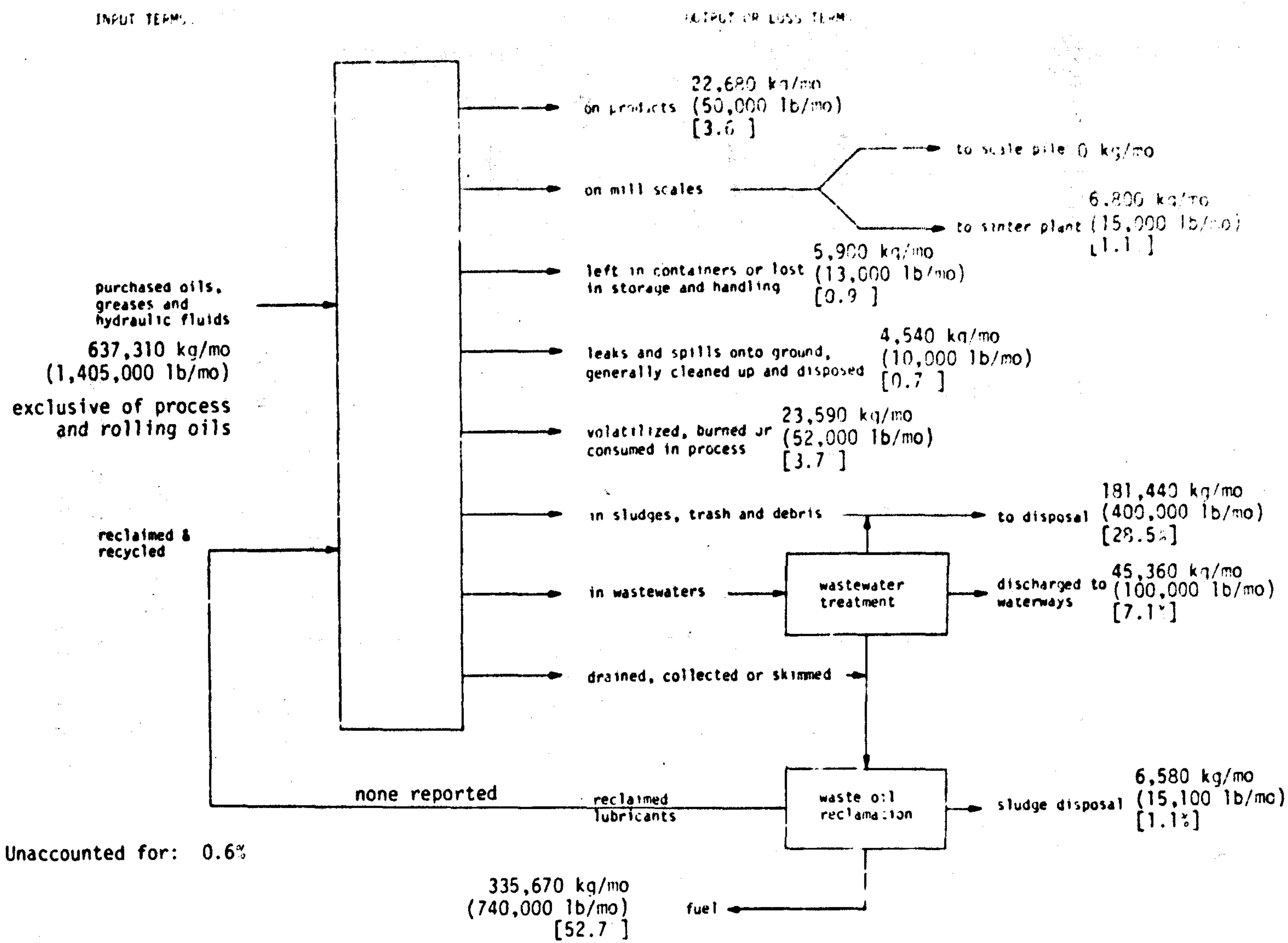


Figure 8-2. MATERIAL BALANCE - UNITED STATES STEEL CORPORATION, GARY

Table 8-2. UNITED STATES STEEL CORPORATION - SOUTH CHICAGO, ILLINOIS*

EQUIPMENT

8	Blast furnaces	
3	Basic oxygen furnaces	
3	Electric arc furnaces	
1	Continuous caster	4 strand - billet

No.	Type of Mill	Annual Rolling Capacity	
1	Slab	1,870,000	3,343,000
2	Blooming	1,473,000	
3	Structural	1,343,700	3,470,900
1	Rod	700,000	
1	Bar	254,000	
2	Plate	1,173,200	
10		6,813,900	Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}}$$

$$= \frac{0}{6.8139 \times 10^6} = 0$$

* Equipment and rolling capacity data from AISI <u>Directory of Iron and Steel Works</u> (1.0 ton = 907.2 kg)

8.3.2.1 Lubricant Purchases. Based on records of actual consumption for the first six months of 1976, the approximate amounts of lubricating oils, greases and hydraulic fluids are as follows:

Oils	82,600 l/month	(21,823 gal/month)
Greases	116,400 kg/month	(256,663 lb/month)
Hydraulic Fluids	40,000 l/month	(10,589 gal/month)

Assuming an average density of 0.90 kg/l (7.5 lb/gal) for lubricating oils and hydraulic fluids, the total input of oils, greases and hydraulic fluids was 2,720,000 kg/yr (5,997,092 lb/yr).

8.3.2.2 Material Balance. Detailed information on lubricant usage and fate could not be obtained for the South Chicago Works so a material balance could not be computed. It is an integrated steel mill, and the use of lubricants is similar to the Gary Works which is also an integrated mill. The South Chicago Works operates a closed loop recycling water system so no oils or greases are discharged from the plant.

8.4 Inland Steel Company, East Chicago, Indiana

A summary of the major equipment and products associated with the Inland Steel Company, Indiana Harbor Works, is presented in Table 8-3. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief the steel production capacity at this Inland Steel facility is 7.4 x 10^9 kg/yr (8.2 x 10^6 tons/yr). The actual production rate during 1975 and 1976, corresponding to the time period for which lubricant purchase data were reported, was 6.5 x 10^9 kg/yr (7.2 x 10^6 tons/yr).

8.4.1 Lubricant Purchases

A tabulation of purchase records, reported by major equipment

Table 8-3. INLAND STEEL COMPANY - EAST CHICAGO, INDIANA *

Equipment

579	Coke ovens - by-product		
8	Blast furnaces		
7	Basic open hearth furnaces		
4	Basic oxygen furnaces		
2	Electric arc furnaces		
1	Continuous Caster	2 strand - slab	1,300,000
1	Continuous Caster	4 strand - billet	500,000
			1,800,000 Net Tons

No.	Type of Mill	Annual Rolling Capacity	
3	Blooming (2 primary, 1 secondary)	4,150,000	
1	Slabbing	3,200,000	8,350,000 Net Tons
1	Billet	1,000,000	
4	Bar	1,275,000	
1	Structural	550,000	
1	Plate	280,000	
3	Hot Strip	6,500,000	19,483,000 Net Tons
5	Strip - Cold reducing	5,925,000	
8	Coil - Cold finishing	4,188,000	
3	Sheet - Cold finishing	765,000	
30		27,833,000	Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} = \frac{17.378 \times 10^6}{27.833 \times 10^6} = .62$$

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works.
(1.0 ton = 907.2 kg)

area, of rolling oils, lubricants, oils and greases; and hydraulic fluids is presented in Table 8-4. In 1975 approximately 13,512,000 l (3,570,000 gal) of oils and greases and 1,890,000 l (500,000 gal) of hydraulic fluids were purchased for the Indiana Harbor Works. Approximately the same quantity of oils, greases and hydraulic fluids was used during 1976. Assuming an average density of 0.90 kg/l (7.5 lb/gal) for lubricating oils and hydraulic fluids, the total input of oils, greases and hydraulic fluids was 13,846,000 kg/yr (30,525,000 lb/yr).

8.4.2 Reclamation and Treatment

Inland Steel reported that in 1975 approximately 2,540,000 l (670,000 gal) of waste oil collected in scale pits and settling basins were sent to the American Recovery Company (ARC) waste oil reclamation plant in East Chicago, Indiana and returned as #6 grade fuel oil. Inland Steel has since began operating a vacuum tank truck for oil recovery purposes, enabling a greater quantity of waste oils to be collected. The truck is available twenty-four hours per day and is typically used to recover oils which previously were cleaned up with oil absorbent materials and disposed of in a landfill. Oil accumulating in the turning basin in the event of an oil spill at the plant or upstream is vacuumed and sent to ARC. Oil drained from trucks, locomotives and other plant vehicles is sent to the terminal treatment plant and then to ARC for reclamation. In 1976, 4,542,000 l (1,200,000 gal) of waste oil were collected in scale pits and settling basins and processed by ARC. Inland Steel purchases the #6 fuel oil which ARC reclaims. In 1976, the Indiana Harbor Works purchased approximately 9.1×10^6 l (2.4×10^6 gal) of fuel oil from ARC or about twice the amount of waste oils sent to ARC. This is possible because some other waste oil sources from which ARC reclaims oil do not purchase the resultant fuel oil. In addition

Table 8-4. ANNUAL USAGE OF LUBRICANTS, OILS, ASES AND HYDRAULIC FLUIDS AT INLAND STEEL - EAST CHICAGO, INDIANA

Rolling Oils, Lubricants, Oils and Greases

Area	Quantity Used	
Hot Strip Rolling Mills	9,270,000 l	(2,450,000 gal)
Coldstrip Rolling Mills	1,990,000 l	(525,000 gal)
Flat and Shape Mills	1,320,000 l	(350,000 gal)
Steelmaking	662,000 l	(175,000 gal)
Blast Furnaces	132,000 l	(35,000 gal)
Coke Plants	132,000 l	(35,000 gal)
TOTAL	13,500,000 l	(3,570,000 gal)

Hydraulic Fluids

Area		
Steelmaking	1,760,000 l	(465,000 gal)
Coke Plants	95,000 l	(25,000 gal)
Miscellaneous	38,000 l	(10,000 gal)
TOTAL	1,893,000 l	(500,000 gal)

Note: These data were estimated by Inland Steel and are representative of calendar years 1975 or 1976.

to these waste oil recovery practices, Bentex, an on-site waste oil reclaimer, recovered approximately 2,650,000 l (700,000 gal) of rolling oils from the cold strip mills [180,000 to 227,000 kg/month (400,000 to 500,000 lb/month)].

To verify and supplement the waste oil recovery data provided by Inland Steel, data was obtained from the Indiana Board of Health, and American Recovery Company was contacted for information. It was determined that the waste oils from the Indiana Harbor Works contain approximately 40 percent oil and 60 percent water. Two percent of the oil is not reclaimed and appears as sludge from the ARC process. The Indiana Board of Health data indicate that during the first nine months of 1976, 4,625,000 l (1,221,830 gal) of waste oil, including water from the Indiana Harbor Works, were handled by ARC. Using this data, it was estimated that an average of about 181,000 kg/month (400,000 lb/month) of #6 fuel oil and 3,600 kg/month (8,000 lb/month) of oily sludge were produced by ARC from Indiana Harbor Works waste oils. There appeared to be some discrepancies in the data or estimates of fuel oil reclaimed by ARC from Inland Steel waste oils. It was assumed by PES that the 4,540,000 l/yr (1,200,000 gal/yr) of waste oils, which were reported by Inland as processed by ARC, actually included 60 percent water. With this assumption it was calculated that about 136,000 kg/month (300,000 lb/month) of fuel oil was reclaimed from Inland Steel waste oils. For material balance estimate purposes it was decided to use values 159,000 kg/month (350,000 lb/month) of fuel oil and 3,200 kg/month (7,000 lb/month) of oily sludge from ARC.

8.4.3 Discharges to Waterways

Wastewater recycle systems are operated which reduce the total volume of discharges to the Indiana Ship Canal and Turning Basin.

Since the NPDES permits were applied for in 1971, Inland has eliminated several outfalls. Currently a total of 14 outfalls are utilized with total maximum oil and grease discharge or concentration limits set on each of these outfalls. At the present time (1976) approximately 1,400 kg/day (3,100 lb/day) of total oil and grease are discharged, or about 4% of the total oils and greases purchased by Inland.

A major wastewater recycle project is planned to recycle all remaining process waters. After the modifications are completed the net oil and grease discharges will be further greatly reduced.

8.4.4 Other Losses

Significant quantities of oils and greases leave the steel mill on the products. Oils and greases become attached to the steel during rolling and are also applied intentionally for rust prevention purposes. Most of the oils and greases which become attached to the steel during rolling are removed by acid washing and pickling prior to the application of metallic coatings. The waste pickle liquor or washing fluid which contain these oils are treated, recycled or disposed of. At the Indiana Harbor Works 582,000 l/yr (153,700 gal/yr) of slushing and coating oils were applied during 1976. An oil mist spray system is employed to apply these coating oils. Excess oil and overspray are collected beneath in a trough and recirculated, minimizing the oil loss or waste. A relatively small amount of excess oil does drip off the coated products and on to the floor or ground in product storage areas. PES assumed that 10 percent of the coating oil is lost by drippage.

Oils and greases on mill scales represent another significant material balance loss term. The oil content of mill scales from some scale pits is reported to reach up to 25 percent by weight. Mill scales typically contain from 0.1 to 2 percent. Data provided by the Indiana Harbor Works indicate that the average oil content of mill scales is 0.4 to 0.5 percent. The total quantity of mill scales collected in scale pits at the Indiana Harbor Works was reported to be 424 x 10^6 kg/yr (467,000 tons/yr). It was estimated that approximately 159,000 kg/month (350,000 lb/month) of oil is contained on mill scales. The sinter plant at the Indiana Harbor Works is equipped with two baghouses. To prevent air pollution control equipment problems (bag fouling) or opacity problems only a small quantity of mil' scale is recycled to the sinter plant. Over 99 percent of the collected mill scales are screened and stockpiled for future recovery. No hydrocarbon tests have been performed on the sinter plant stack and no estimates of the hydrocarbon emission rate were available.

Sludges generated in various areas of the plant such as the clarifiers and terminal treatment plant at the Indiana Harbor Works contain oils and greases. Data provided by Inland Steel indicate that about 175 x 10^6 kg/yr (193,000 tons/yr) of sludge on a dry basis is generated. Sludges are landfilled or stockpiled for future use at the steel mill. The sludges generally contain 60 percent water and are removed from clarifiers by tank truck and hauled to a landfill. The three major sources of sludge and the corresponding oil contents are as follows:

Sludge Source	Quantity of Sludge (kg/yr)	Quantity of Sludge (Dry Tons/Yr)	Oil Content (Percent)
Blast furnace	64.9 x 10^6	71,500	0.1
Basic oxygen furnaces	46.7 x 10^6	51,500	0.01
Terminal treament plant	28.6 x 10^6	31,500	3.7
	140.2 x 10^6	154,500	

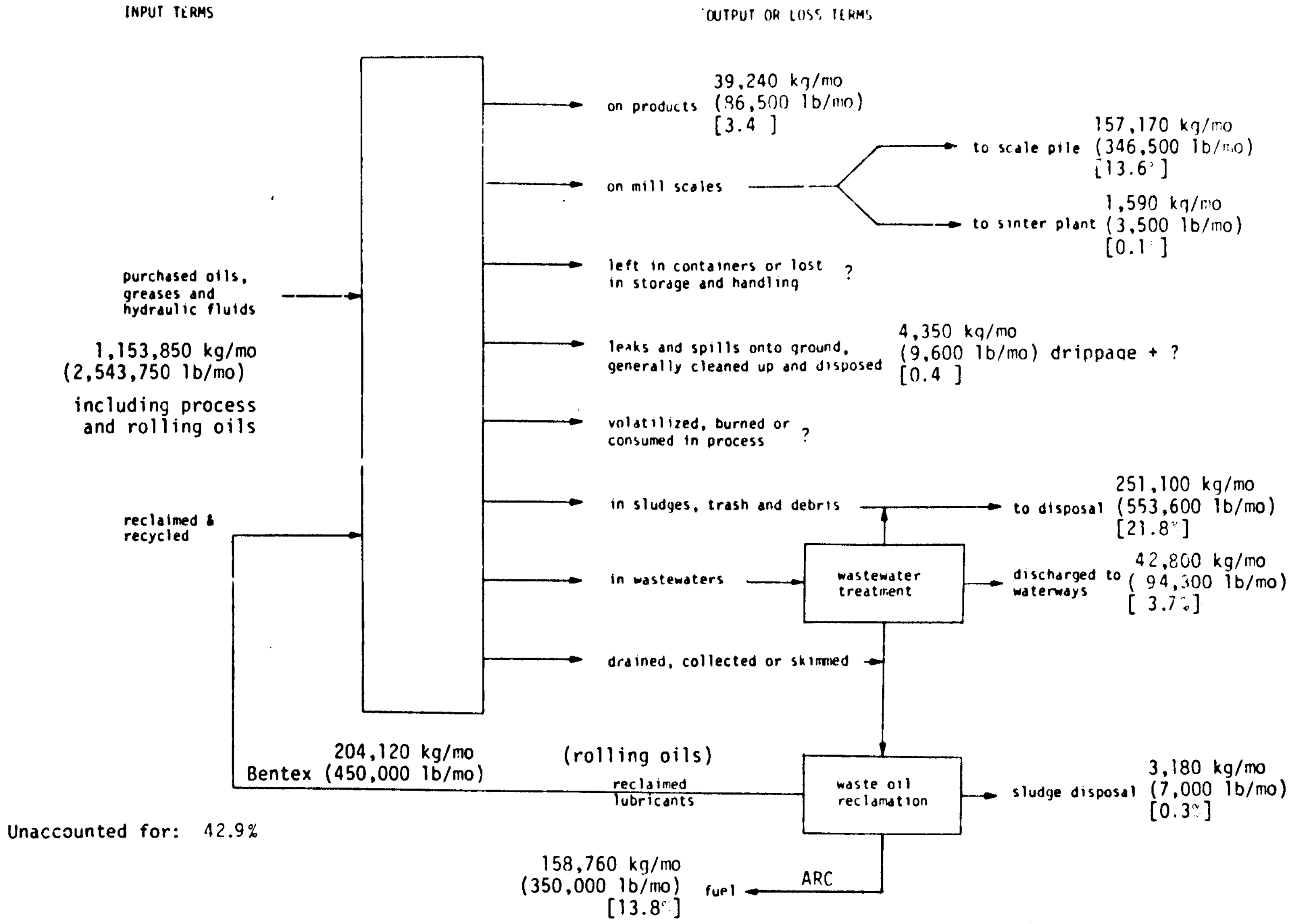


Figure 8-3. MATERIAL BALANCE - INLAND STEEL COMPANY, INDIANA HARBOR WORKS

Coke oven, slab caster and miscellaneous sludges, all containing low oil contents (assume 0.1 percent), account for the remaining 34.9 x 10^6 (38,500 dry tons/yr) of sludge. From this information, it was calculated that 242,000 kg/month (533,600 lb/month) of oils and greases are contained in sludges. This represents approximately 21 percent of the total input of oils, greases and hydraulic fluids.

8.4.5 Material Balance

Reclaimed oil (as fuel oil), oil and grease in wastewater discharges, oil in sludges and on mill scales, and oil lost on products account for 56.7 percent of the total oil, greases and hydraulic fluids used annually by Inland Steel at the Indiana Harbor Works. Figure 8-3 summarizes the material balance estimate and loss term data available for the mill. For the conversion of volume to weight units for oils, greases and hydraulic fluids a density of 0.9 kg/l (7.5 lb/gal) was assumed. Shown on the material balance illustration are usage rate values and the percent of the total input represented by each loss term for which data was obtained. No data or estimates were obtained for oils, greases and hydraulic fluids left in containers or lost in storage and handling; or volatilized, burned or consumed in process. These unknown terms and the uncertainty of other estimated loss terms could account for the missing 42.9 percent.

8.5 Youngstown Sheet and Tube Company, East Chicago, Indiana

A summary of the major equipment and products associated with the Youngstown Sheet and Tube Company, East Chicago plant, is provided in Table 8-5. The information presented in the table is a summary of the data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief

Table 8-5. YOUNGSTOWN SHEET AND TUBE COMPANY - EAST CHICAGO, INDIANA*

Equipment

237 Coke ovens - by-product
4 Blast furnaces
8 Basic open hearth furnaces
2 Basic oxygen furnaces

No.	Type of Mill	Annual Rolling Capacity	
1	Slab	2,604,000	4,512,000 Net Tons
1	Blooming	1,200,000	
1	Billet	708,000	
2	Bar	504,000	8,216,000 Net Tons
1	Hot Strip	3,000,000	
2	Tin - Cold reduing	764,000	
1	Tin - Cold finishing	408,000	
1	Sheet - Cold reducing	900,000	
4	Sheet - Cold finishing	2,640,000	
14		12,728,000	Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} = \frac{7.712 \times 10^6}{12.728 \times 10^6} = .61$$

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works.

(1.0 ton = 907.2 kg)

the steel production capacity of the East Chicago plant is 5.0 × $10^{[illegible]}$ kg/yr (5.5 × [illegible] tons/yr).

8.5.1 Lubricant Purchases

Lubricant usage data, reported by major department or plant area, are presented in Table 8-6. For lube oils, hydraulic fluids and greases a range of gallons or pounds per raw ton of steel produced were reported. Assuming that the production level during 1976 was approximately 70% of capacity, the total quantities of lube oils, hydraulic fluids and greases were estimated as follows:

Lube oils	915,600 l/month	(241,910 gal/month)
Process and rolling oils	152,800 l/month	(40,360 gal/month)
Hydraulic fluids	438,400 l/month	(115,820 gal/month)
Greases	834,250 l/month	(220,410 lb/month)

Assuming 0.90 kg/l (7.5 lb/gal) for oils and hydraulic fluids, the total lube oil, process oil, grease and hydraulic fluid input to the plant is 17,450,000 kg/yr (38,473,000 lb/yr).

The data indicated that the hot strip mill uses roughly 70 percent of all lube oils, hydraulic fluids and greases purchased at the East Chicago plant. Youngstown Sheet and Tube has broken down the various lubricants used at the East Chicago facilities into 36 basic specifications. Currently 20 different suppliers provide some 120 different products that fall into the basic categories.

8.5.2 Reclamation and Treatment

Waste oil recovery efforts depend upon the type of oil that is collected. Different types of mechanical equipment are utilized to remove floating and insoluble oils. In the case of soluble solutions, a chemical pretreatment is generally used, followed by

Table 8-5. LUBRICANT USAGE* PER RAW TON OF STEEL PRODUCED

	Lubricating Oils (gal)	Hydraulic Fluids (gal)	Greases (lb)
Coke Plant	.007 / .017	.001 / .002	.002 / .009
Blast Furnace	.004 / .006	-	.024 / .033
B.O.F.	.001 / .002	.001 / .002	.010 / .020
Slab.	.075 / .125	.005 / .007	.100 / .115
Pipe	.026 / .030	.039 / .045	.060 / .075
Tin Mill	.020 / .030	.010 / .025	.005 / .008
Sheet	.020 / .045	.010 / .025	.005 / .008
HSM	.500 / .600	.250 / .300	.400 / .500
TOTAL	.653 / .855	.316 / .406	.606 / .768
AVERAGE	.754	.361	.687

*Note: In addition, 3,000,000 lb/yr (.545 lb/ton) of rolling oil and 632,600 lb/yr (.1 5 lb/ton) of coating oils are used.

(1.0 gal/ton = 4.172 l/1,000 kg)

(1.0 lb /ton = 0.50 kg/1,000 kg)

mechanical or chemical flocculation before removal. The disposal of collected waste oils is handled in several ways:

- Waste oils are shipped to outside processors for cleanup and then used as fuel;
- Some waste oils are recycled in the plant fuel oil system;
- The company has been experimenting with off-site re-refining of waste oils for reuse as lubricants.

Data obtained from the Indiana Board of Health and American Recovery Company, Inc. indicate that during 1976 about 5,910,000 l (1,561,500 gal) of waste oil (containing 60 percent H_2O) was processed in ARC's East Chicago facility. It was estimated that 98 percent of the reclaimed oil [2,317,000 l/yr (612,100 gal/yr)] is returned to Youngstown Sheet and Tube as a fuel oil. The sludge or waste oil unsuitable for reuse is estimated to be about 2 percent or 47,000 l/yr (12,500 gal/yr).

8.5.3 Discharges to Waterways

The NPDES Permit was reviewed to obtain discharge rate data for the Youngstown Sheet and Tube Company, East Chicago plant. A major wastewater discharge modification program is planned which will eliminate four of the eleven outfalls by December 31, 1978. At the present time, approximately 5,590 kg/day (12,330 lb/day) of total oil and grease are discharged into the Indiana Harbor Canal and Inner Harbor. After the modifications are completed, which will enable the segregation of non-contact cooling waters from process wastewaters, the total oil and grease discharge rate will be 1,533 kg/day (3,380 lb/day).

8.5.4 Other Losses

Oils and greases on the products, applied intentionally for rust prevention or picked up during rolling and finishing, are recognized as a significant material balance loss term. Most oils and greases which become attached to the steel during rolling are removed by acid washing and pickling prior to the application of metallic coatings. The waste pickle liquor or washing fluid which contain these oils, are treated, recycled or disposed of. At the Youngstown Sheet and Tube's East Chicago Plant, 286,950 kg/yr (632,600 lb/yr) of slushing and coating oils were purchased during 1976. No data was supplied by the mill regarding the fate of these oils, but other mills have indicated that 90 percent of the purchased coating oils leave on products and the remaining 10 percent drip off.

Oils and greases on mill scales represent another significant material balance loss term. Mill scales are dredged from scale pits and are either 1) recycled to the sinter plant where the oils and greases are volatilized by the slow moving flame front during sintering; 2) stockpiled for future recovery of the metal values due to the excessive oil content causing air pollution control equipment or opacity problems; or 3) disposed of in landfills. Mill scales typically contain 0.1 to 2 percent oil by weight although mill scales with considerably higher oil contents have been reported. At the East Chicago plant approximately 90.7×10^6 kg (100,000 tons) of mill scale are recycled annually through the blast furnace or the sinter plant. The average oil content of this mill scale is reported to vary between 0.15 to 0.40 percent. From this data it was estimated that roughly 20,900 kg/month (46,000 lb/month) of oil is accounted for on recycled mill scale. It is thought that mill scales recycled to the sinter plant are volatilized rather than combusted. No stack test data on hydrocarbon emissions from the sinter plant are available. An electrostatic precipitator is installed on the sinter breaker stack. Oils on mill scales recycled to the blast furnaces are thought to be combusted. For material balance estimation purposes, it was assumed that half of these mill scales are sintered and half are recycled directly to the blast furnace.

An additional 5.4 x 10^6 kg/yr (6,000 tons/yr) of mill scale is stockpiled for future use due to excess oil content. This mill scale has a reported average oil content of 5 to 9 percent. Approximately 31,750 kg/month (70,000 lb/month) of oil are accounted for by stockpiled mill scale.

Sludges generated in various areas of the plant can contain significant quantities of oil. Youngstown Sheet and Tube reported that approximately 27.2 x 10^6 kg/yr (30,000 tons/yr) of sludge are removed from the wastewater treatment facilities at the East Chicago plant. The average oil content of this sludge is 30 percent. This sludge, containing 680,000 kg/month (1,500,000 lb/month) of oil, is disposed of at various off-site landfill locations.

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during handling and storage;
- oils and greases contained on trash and debris which are collected and sent to a solid disposal area;
- quantities volatilized, burned or otherwise consumed in use in the various steel making and shaping processes;
- leaks and spills on to the floors or ground which are cleaned up and disposed of.

No data or estimates of these miscellaneous loss terms could be provided by Youngstown Sheet and Tube.

8.5.5 Material Balance

Using the data presented above, an attempt was made to develop an overall material balance for total oils, greases and hydraulic fluids. Quantifying each of the loss terms identified in Figure 8-4 is a difficult task. Estimates were made based on data obtained from several sources, including Youngstown Sheet and Tube Company, American Recovery Company, Indiana Board of Health, and EPA Region V. For the conversion of volume to weight units for oils, a density of 0.9 kg/l (7.5 lb/gal) was assumed. Shown on the material balance illustration are kg/month values for several terms and the percent of the total input represented by each loss term. Loss estimates account for 75.9 percent of all purchased lubricants. The remaining 24.1 percent could be accounted for by lubricants left in containers, spilled onto the ground, volatilized or burned, and by uncertainties or errors in the estimated loss terms.

8.6 Bethlehem Steel Corporation, Sparrows Point, Maryland

A summary of the major equipment and products associated with the Bethlehem Steel Corporation Sparrows Point facility is provided in Table 8-7. The information presented in the table is a summary of the data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief the steel production capacity at Sparrows Point is 6.8×10^9 kg/yr (7.5×10^6 tons/yr). The actual production rate for the first six months of 1976, corresponding to the time period for which lubricant usage data were reported, was approximately 418×10^6 kg/month (461,270 tons/month) or 5.0×10^9 kg/yr (5.5×10^6 tons/yr).

8.6.1 Lubricant Purchases

Lubricant usage data, reported by major department or plant area, are presented in Table 8-8. A total of 609,000 l/month (161,000 gal/month) of oils and hydraulic fluids, and 149,000 kg/month (329,000 lb/month) of greases are utilized. Of the 609,000 l/month (161,000 gal) of oils and hydraulic fluids, 40 percent [242,000 l (64,000 gal)] are hydraulic fluids and 60 percent [365,600 l

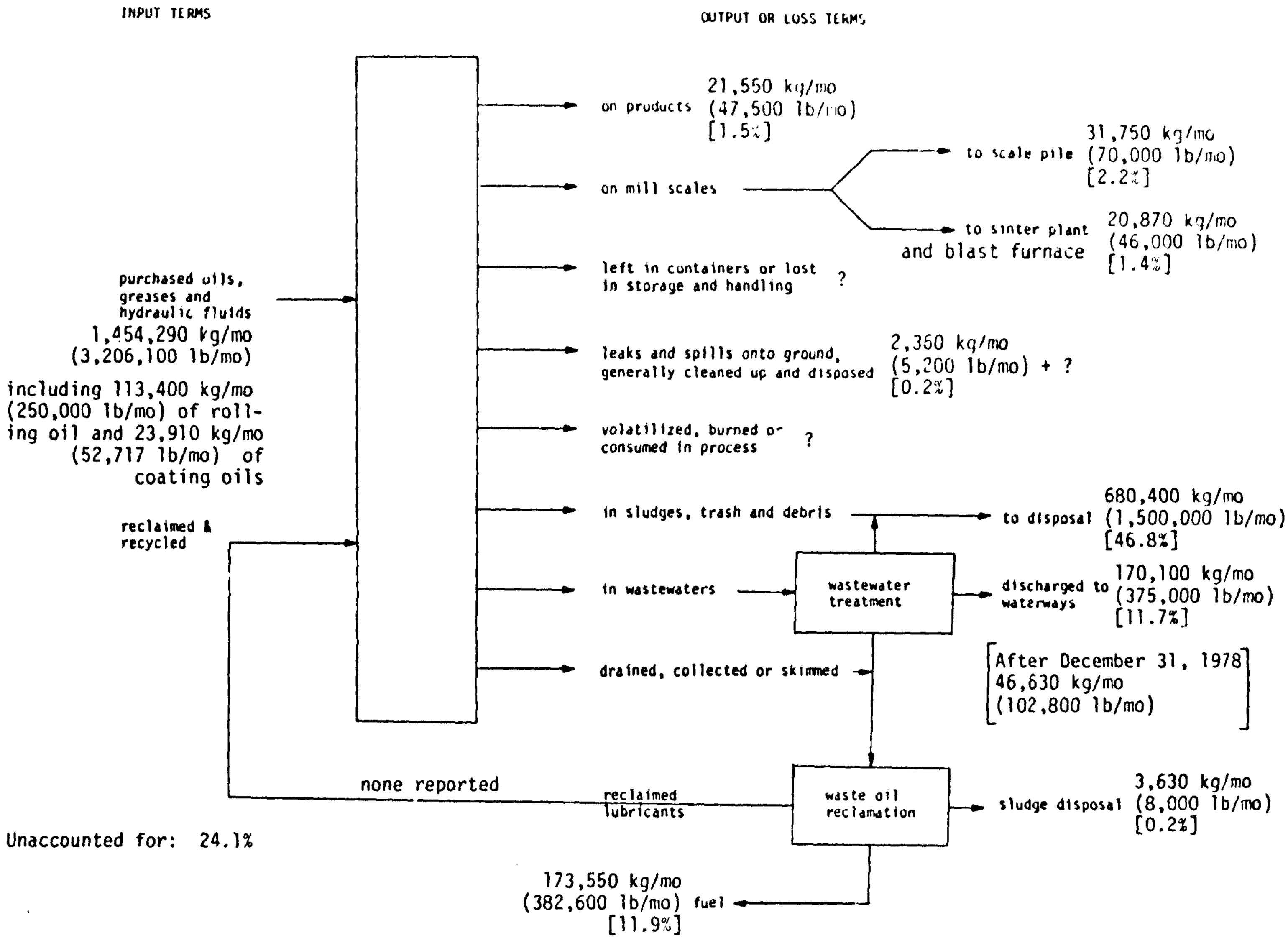


Figure 8-4. MATERIAL BALANCE - YOUNGSTOWN SHEET AND TUBE COMPANY, EAST CHICAGO

TABLE 8-7. BETHEHEM STEEL CORPORATION - SPARROWS POINT, MARYLAND*

Equipment

757 Coke ovens - by-product
10 Blast furnaces
7 Basic open hearth furnaces
2 Basic oxygen furnaces

No.	Type of Mill	Annual Rolling Capacity	
2	Slab	5,320,000	10,300,000 Net Tons
2	Blooming	2,910,000	
2	Billet	2,070,000	
2	Rod and bar	758,000	13,883,000 Net Tons
2	Plate	1,160,000	
2	Hot strip	5,210,000	
5	Tin - Cold reducing	2,040,000	
2	Sheet - Cold reducing	1,930,000	
4	Sheet - Cold finish - temper	1,360,000	
4	Tin - Cold finish - temper	1,425,000	
27		24,183,000 Net Tons	

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} = \frac{11.965 \times 10^{6}}{24.183 \times 10^{5}} = .49$$

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works.

(1.0 ton = 907.2 kg)

Table 8-8. AVERAGE MONTHLY CONSUMPTION DATA FOR BETHLEHEM STEEL - SPARROWS POINT

Plant Area	Oils and Hydraulic Fluids	Greases
Coke Ovens	2,000	3,000
Blast Furnace Section	2,000	13,000
Steelmaking Section	2,000	12,000
Primary Mills	5,000	90,000
Plate Mills	7,000	50,000
Hot Strip Mills	48,000	107,000
Cold Sheet Mills	22,000	10,000
Tin Mills	43,000	24,000
Rod and Wire Mills	12,000	3,000
Pipe Mills	4,000	5,000
Shops, Etc.	14,000	12,000
TOTAL	161,000 gal.*	329,000 lb.

*Note: 40% HF - 64,400 gals.hydraulic fluids
60% Oils - 96,600 gal. oils
161,000 gals.

It was estimated by PES that 55,000 gal/month of fresh or makeup rolling oil is used in addition to the oils reported above.

(1.0 gal = 3.785 l)
(1.0 lb = 0.4536 kg)

(96,600 gal)] are oils. Also rolling oil is used which is reclaimed and recycled. The exact amount of fresh rolling oil makeup is unknown but approximates 208,000 l/month (55,000 gal/month). Assuming 0.9 kg/l (7.5 lb/gal) for oils, the total oil, grease and hydraulic fluid input to the plant is 884,000 kg/month (1,949,000 lb/month) or 10,610,000 kg/yr (23,388,000 lb/yr). Primary and secondary shaping and rolling mills account for about 90 percent of the oils, greases and hydraulic fluids used at the Sparrows Point facility.

8.6.2 Reclamation and Treatment

Waste oil recovery efforts include the use of several oil skimmers on scale pits, at various locations along the wastewater canal and in the Humphreys Creek Wastewater Treatment Plant. American Recovery Company, Inc. and PORI, Inc. both process waste oils for the Bethlehem Steel plant. ARC converts the waste oil into fuel oil, and PORI reclaims rolling oil. Cold strip and tin mill rolling solutions are collected and pumped to PORI for reclamation of rolling oils which are returned for reuse. Approximately 406,000 kg or 452,000 l/month (895,550 lb or 174,641 gal/month) of rolling oils were applied in the cold strip and tin mills. [97,300 kg/month (214,548 lb/month) applied at the cold strip mill and 496,800 kg/month (1,095,260 lb/month) applied at the cold tin mill)]. From these data it appears that about 208,000 l/month (55,000 gal/month) of fresh rolling oil are required.

Plant waste oil boxes, used for collecting floating waste oils drained and collected throughout the plant or recovered from the various scale pits and oil skimmers, are accumulated in a central waste oil pit from which oils are reclaimed by American Recovery Company (ARC). An average of 122,000 kg or 135,700 l/month (268,950 lb or 35,860 gal/month) are reclaimed by ARC and returned as fuel oil to the plant fuel system.

Final wastewater treatment at the Humphreys Creek WWTP includes: pH control, aeration, sedimentation, sludge removal, final oil removal (skimmers), and final aeration before discharge to Bear Creek. Several opportunities for floating waste oil recovery are provided at Sparrows Point. Oil skimmers have been installed at scale pits and at fixed floating baffles installed in the wastewater canal. This effectively reduces the total oil and grease load on the Humphreys Creek WWTP. Within the plant, waste oil containers are used to handle leaks and spills thus reducing the amount of oils entering the wastewater system.

8.6.3 Discharges to Waterways

Discharge data for the three outfalls for which total oil and grease sampling and analysis is performed was obtained from the Maryland Department of Water Resources. Grab samples taken once per week at Outfall 013, which services the hot forming section of the plant, contained an average of 564 kg/day (1244 lb/day). The primary mills discharging into Outfall 013 have been diverted to the treatment plant which discharges the Outfall 015. Outfall 014 handles wastes from the rod mill, wire mills, hot forming, cold rolling, pickling and coating processes and contains an average of 2995 kg/day (6604 lb/day) (based on monthly data from July 1975 to September 1976.). While mass emission rate data for Outfall 017 was not available, the total oil and grease concentration averaged 6.5 mg/l. Outfall 017 services the garage and boiler rooms. Based on average flow rate data, it is estimated that Outfall 017 discharges about 28.5 kg/ day (62.7 lb/day) of total oil and grease. The total average oil and grease discharge rate from these three outfalls is 3590 kg/day (7910 lb/day or 237,300 lb/month). A total of 15 outfalls discharge water from the Bethlehem facility, and the total oil and grease discharge rate for the entire plant is estimated at about 113,000 to 136,000 kg/month (250,000 to 300,000 lb/month). This represents roughly 13 to 15 percent of the total oils, greases and hydraulic fluids input to the entire steel mill.

8.6.4 Other Losses

As mentioned previously, significant quantities of oil and grease leave the steel mill on products. Oil and grease become attached to the steel during the rolling process and are also applied intentionally for rust prevention. At the Sparrows Point plant Bethlehem Steel estimates that in the cold-strip mill, 75 percent of the 38,600 l/month (10,200 gal/month), or 29,000 l/month (7650 gal/month), of slushing oils leave on products. The remaining 25 percent is lost as drippage. The following estimates of oils and preservatives were provided for the cold-tin mill:

	L/Month	(Gal/Month)
Alkaline Lines	3,400	(900)
#8 Chrome Line	4,350	(1,150)
#6 Cleaning Line	3,000	(800)
Halogen Lines (Tin Plating)	6,000	(1,750)
Cold Tin Mill Total	17,400	(4,600)

The total quantity of oils contained on products at Sparrows Point was estimated to be 46,400 l/month (12,250 gal/month) or 41,675 kg/month (91,875 lb/month).

Mill scale collected from various scale pits is recycled to the sinter plant equipped with high energy scrubbers. Oils and greases contained on the mill scales are volatilized during sintering and either condensed and captured by the scrubber or are emitted to the atmosphere. At the Sparrows Point plant, mill scales collected from various scale pits are sent to temporary storage and subsequently recycled to the sinter plant. Only the very oily mill scales are not recycled to the sinter plant. Approximately 13.6 x 10^6 kg/month (15,000 tons/month) of mill scale, with an average oil content of 0.15 percent, is sintered. The 20,400 kg/month (45,000 lb/month) of oil in mill scales is volatilized. Stack test data from the sinter plant indicate that about 20.4 kg/hr (45 lb/hr or 32,400 lb/month) of hydrocarbons are emitted. It appears that approximately 72 percent of the hydrocarbons resulting from volatized oils in mill scale are emitted to the atmosphere. The remaining 28 percent are either condensed and captured by the high energy scrubbers or combusted in the sinter plant.

Sludges generated in various areas of the plant and by the waste oil reclaimers contain oils and greases. The following summary of quantities of sludges containing oils was provided by the steel mill:

Humphreys Creek Waste Water Treatment Plant	118×10^3 kg/day	130 T/day
Cold Strip Mill	18×10^3 kg/mo	20 T/mo
Cold Tin Mill	27×10^3 kg/mo	30 T/mo
Pipe Mill	9×10^3 kg/mo	1 T/mo
Wire and Rod Mills	9×10^3 kg/mo	1 T/mo
PORI	454×10^3 kg/yr	500 T/yr
American Recovery	27×10^3 kg/mo	30 T/mo

It was reported that the oil content of these sludges ranged from five to twelve percent with an average oil content of ten percent. All sludges are disposed of by landfill. The wastewater treatment plant sludges contain about 353,800 kg/month (780,000 lb/month) of oil while the other plant sludges account for an additional 4,700 kg/month (10,400 lb/month) of oil. The oils in waste oil reclaimer (PORI and ARC) sludges is estimated to be 6,490 kg/month (14,300 lb/month). The total quantity of oils in all steel mill and waste oil reclaimer sludges is 365,000 kg/month (804,700 lb/month).

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during handling and storage;
- Oils and greases contained on trash and debris which are collected and sent to a solid waste disposal area;

- quantities volatized, burned or otherwise consumed in use in the various steel making and shaping processes;
- leaks and spills on the floor or ground which are generally cleaned up and disposed of.

While data for these various loss terms is not available, Bethlehem Steel did provide a tabulation by plant area of the percentages of maintenance oils and hydraulic fluids accounted for by several loss terms. The tabulation does not include oils applied on products or rolling oils reclaimed by PORI. For each plant area, such as the tin mills, Table 8-9 provides an estimation of the distribution of loss terms or fate of the lubricants and hydraulic fluids used by the plant area. The last entry, labeled "Plant," provides a general or overall accounting of loss terms. The steel mill has indicated that for the entire plant, approximately sixty percent of the maintenance oils and hydraulic fluids are contained in wastewaters or mill scales. Fifteen percent of the oils and hydraulic fluids are collected and sent to American Recovery Company. Oils in trash are handled as solid waste and account for 15 percent. Of the remaining oils, three percent is lost via leaks and spills which are cleaned up and disposed of, five percent is left in containers, and two percent is volatized, burned or consumed in process. The lubricants and hydraulic fluids left in containers may be removed or combusted by a barrel reclaimer, returned to the lubricant supplier or discarded with trash.

8.6.5 Material Balance

The data obtained in response to the PES questionnaire, information noted during a plant visit, discharge data extracted from files at the Maryland Department of Water Resources and estimates based on data collected at other steel mills included in the survey were used to develop a material balance for oils, greases and hydraulic fluids for the Bethlehem Steel Corp., Sparrows Point Plant. As illustrated in Figure 8-5 input and output or loss terms are reported on a mass basis. Also shown on the material balance illustration is the percent of the total input represented by each loss term.

Table [illegible]. ESTIMATED MISCELLANEOUS LOSSES OF MAINTENANCE LUBRICANTS AND HYDRAULIC FLUIDS - SPARROWS POINT PLANT

	Fate of Lubes by Department - (percent)					
	CATEGORY					
	1	2	3	4	5	6
Coke Ovens	10	50	10	20	10	-
Blast Furnace	-	15	60	15	5	5
Steelmaking	-	10	25	15	5	45
Primary Mills	51	20	20	5	4	-
Plate Mills	70	12	15	-	3	-
Hot Strip Mill	90	5	3	-	2	-
Cold Sheet Mill	50	25	20	-	5	-
Tin Mills	60	20	15	-	5	-
Pipe Mill	20	40	30	5	5	-
Rod and Wire Mill	85	7	5	-	3	-
Shops	10	35	45	5	5	-
Plant	60	15	15	3	5	2

Categories

1. In Waste Water and Mill Scale
2. Waste Oil to American Recovery
3. In Trash; Handled as Solid Waste
4. Leaks and Spills (cleaned up & disposed)
5. Left In Containers
6. Volatized, Burned. Etc.

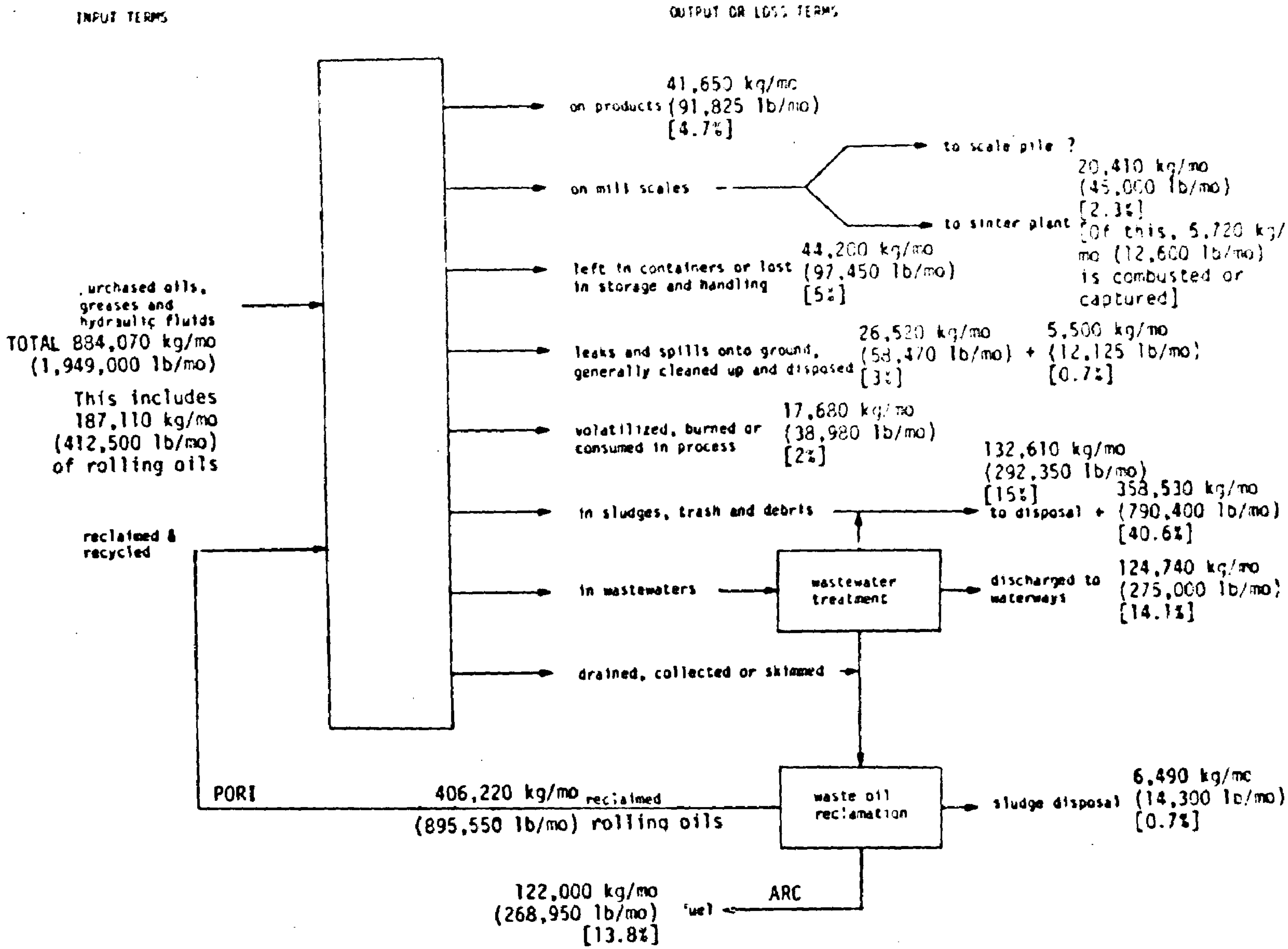


Figure 8-5. MATERIAL BALANCE - BETHLEHEM STEEL CORPORATION, SPARROWS POINT

PES and Bethlehem Steel estimates were used to complete the balance. The loss terms or categories for which Bethlehem Steel provided estimates were not the same as in the PES material balance estimate. For example, oil losses in wastewater and mill scales are estimated as one term by the steel mill. The waste oil to ARC term agrees with information available to PES. The oil in trash quantity reported by the steel mill apparently does not include oily sludges. Process and rolling oils were not included in the Bethlehem Steel estimates. Nevertheless, the estimates provided for losses as leaks and spills, in trash, left in containers, and volatized or burned in process appear reasonable and were used by PES in the material balance estimate provided in Figure 8-5. Totalling the loss term percentages calculated by PES, and including the four percentages estimated by the steel mill, a value of 102.2 percent is obtained. Uncertainty in calculated loss terms, such as oil in sludges, wastewater or on mill scales, could easily account for the apparent 2.2 percent error.

8.7 Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania

A summary of the major equipment and products associated with the Jones and Laughlin Steel Corporation, Aliquippa Works, is presented in Table 8-10. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief the total steel production capacity at Aliquippa is 3.48×10^9 kg/yr (3.84×10^6 tons/yr). The actual production rate during 1975, corresponding to the time period for which lubricant usage data were reported, was 1.8×10^9 kg/yr (2×10^6 tons/yr).

8.7.1 Lubricant Purchases

A list of lubricants, oils, greases, hydraulic fluids and protective coatings, including quantities purchased for use at the Aliquippa

TABLE 8-10. JONES AND LAUGHLIN STEEL CORP. - ALIQUIPPA, PENNSYLVANIA*

Equipment

271	Coke ovens by-product
5	Blast furnaces
3	Basic oxygen furnaces
1	Continuous caster - 6 strands - billets

No.	Type of Mill	Annual Rolling Capacity	
1	Blooming	2,115,000	4,488,400 Net Tons
2	Billets & sheet bars	1,810,000	
1	Round	563,400	
1	Bar	409,000	3,705,200 Net Tons
1	Rod	433,000	
1	Hot strip	1,536,000	
5	Sheet or tin	1,327,200	
12		8,193,600	Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} =$$

$$\frac{2.8632 \times 10^{6}}{8.1936 \times 10^{6}} = .35$$

*Equipment and annual rolling capacity data from AISI <u>Directory of Iron and Steel Works</u>.

(1.0 ton = 907.2 kg)

Works in 1975 is presented in Table 8-11. These materials are used throughout the plant. The usage data provided by the mill did not appear to include rolling oil. PES estimated that 37,850 l/month (10,000 gal/month) of rolling oil is used at Aliquippa. The total plant usage amounts to approximately 5,408,000 kg/yr (or 11,922,000 lb/yr) with the purchases of the three major users of lubricants within the Aliquippa Works reported as follows:

Department	Annual Lubricant Purchases in Thousands of kg	lb	Usage Rate in kg/1000 kg of Steel Processed	lb/ton of Steel Processed
Strip Mill	460	(1,016)	0.55	(1.11)
Rod and Wire	435	(960)	0.98	(1.97)
Tin Plate	751	(1,656)	0.37*	(0.74*)

*Note: The usage rate value for the Tin Plate Department is based on multiple processing steps, including pickling, cold rolling annealing and tin plating. A given piece of steel product may be subject to more than one processing step.

8.7.2 Reclamation and Treatment

Oils, lubricants and fluids used in vehicles and tractors at the steel mill are generally drained and collected. Relatively small quantities would be expected to be consumed (volatized) in use, oxidized or leak to the floor or ground. Annual purchases of these materials total 67,750 l (17,900 gal) or 60,900 kg (134,250 lb).

For material balance development purposes it was estimated that approximately 80 percent of these lubricants are drained and collected for reclamation or disposal. Half of the remaining 20 percent was assumed to be consumed or lost in use, with the remaining amount leaking from the vehicles or lost during changing.

Table 8-11. LUBRICANT PURCHASES - 1975

<u>Oils</u>	
Lubricating Oils	275,000 gal.
Motor Oil	15,000 gal.
Dexron, Brake Fluid & Penetrating Oil	1,800 gal.
Transmission Lubes	1,100 gal.
Soluble Oils	61,000 gal.
Cutting Oils	153,000 gal.
Pipe Coating Oils	154,000 gal.
Rust Preventatives	18,200 gal.
Slushing Oils	5,200 gal.
	684,300 gal.
<u>Greases</u>	
Wire Drawing Compounds	16,000 lb.
A.P.I. Modified Thread Compounds	97,000 lb.
E.P. Gear Lubricants	900,000 lb.
Greases	2,700,000 lb.
Casting Lube	9,200 lb.
	3,722,200 lb.
<u>Hydraulic Fluids</u>	
Hydraulic Oils	220,000 gal.
Fire Resistant Fluids	69,000 gal.
	289,000 gal.

Note: PES estimated that in addition to the above oils, 10,000 gal/month of rolling oil is used. (1.0 gal = 3.785 l and 1.0 lb = 0.4536 kg)

It was reported that a study will be made to determine if waste oil collected in scale pits and various oil skimming locations can be reclaimed and returned as fuel or lubricating oil. Currently 45,420 l/month (12,000 gal/month) of hydraulic and lubricating oils are collected and centrifuged for reuse in certain tin, rod and welded tube mill areas. Approximately 1,140 l/month (300 gal/month) from the machine shop steam cleaning operation is collected and forwarded to an oil reclaimer. The five-stand tandem cold mill utilizes a recycle water system. Fats skimmed from tanks in this system are delivered to an oil recovery unit which produces oil which is recycled to the pickle line oiler and also oil that is sent to an outside purchaser (a waste oil scavenger).

According to information provided by PORI, recovery equipment to reclaim rolling fats was installed and is operated on a fee basis by PORI on the 5-stand tin mill (direct application lubrication). The oil recovery system was designed to handle a water flow of 760 l/min (200 GPM) and recover 68,000 kg/month (150,000 lb/month) of rolling oils. The PORI system is capable of returning 27,000 kg/month (60,000 lb/month) to the mill. The water is recirculated to the tin mill with a blowdown to the chemical rinse treatment plant. Reclaimed rolling oils are used in the pickle line oiler.

8.7.3 Discharges to Waterways

Wastewater treatment is performed in two separate systems illustrated, in Figures 8-6 and 8.7. One treatment system (see Figure 8-6) is currently treating wastewaters from the 35.6 cm (14-inch) mill, hot-strip mill and welded-tube mill. Future plans for this system call for handling wastewaters from the bar, billet and blooming mills and seamless and round mills. Oil skimmers to remove floating oil have been installed at the clarifiers and

ALIQUIPPA WORKS

COMBINED TREATMENT OF HOT MILL SCALE PIT DISCHARGES

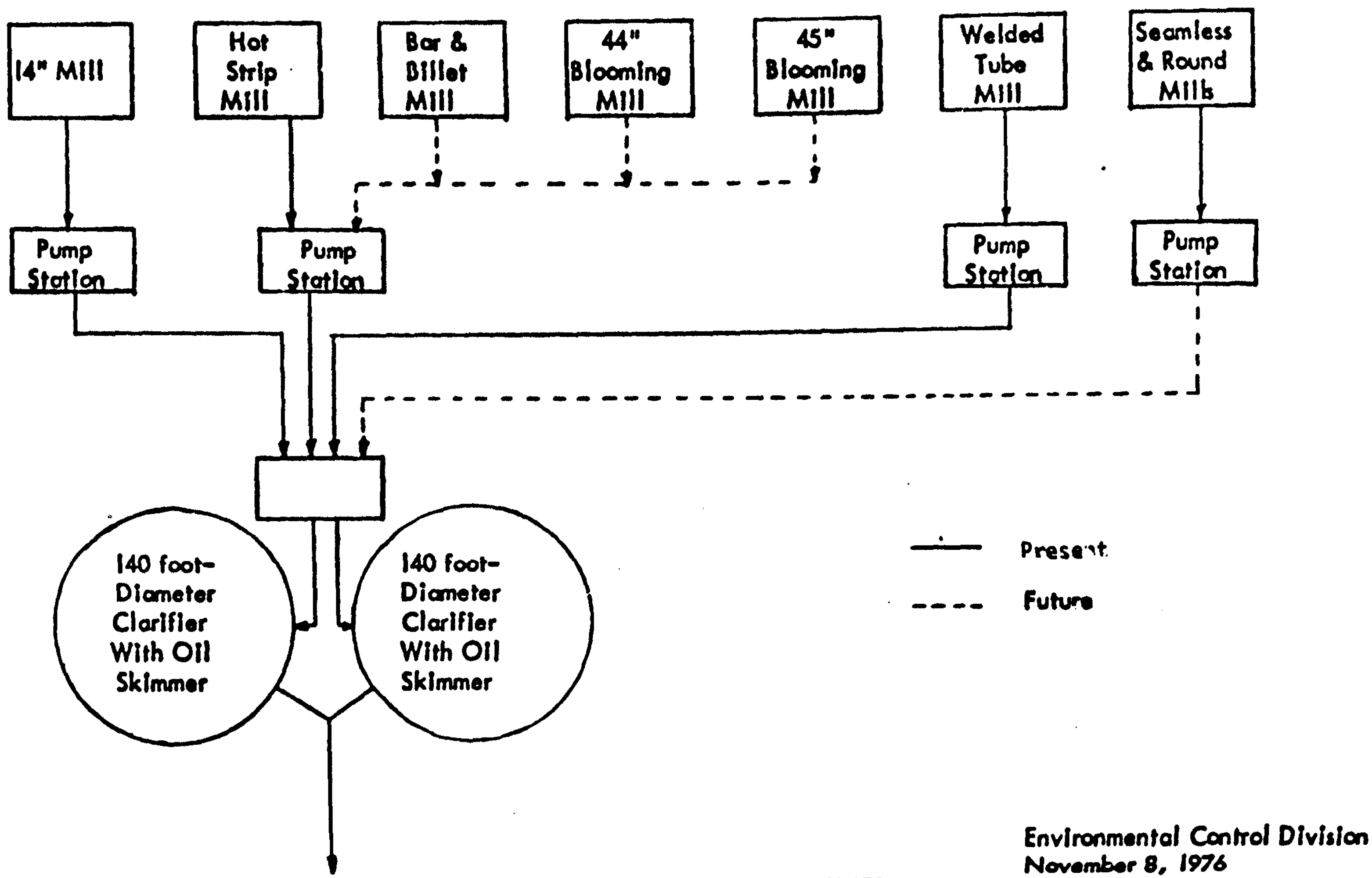
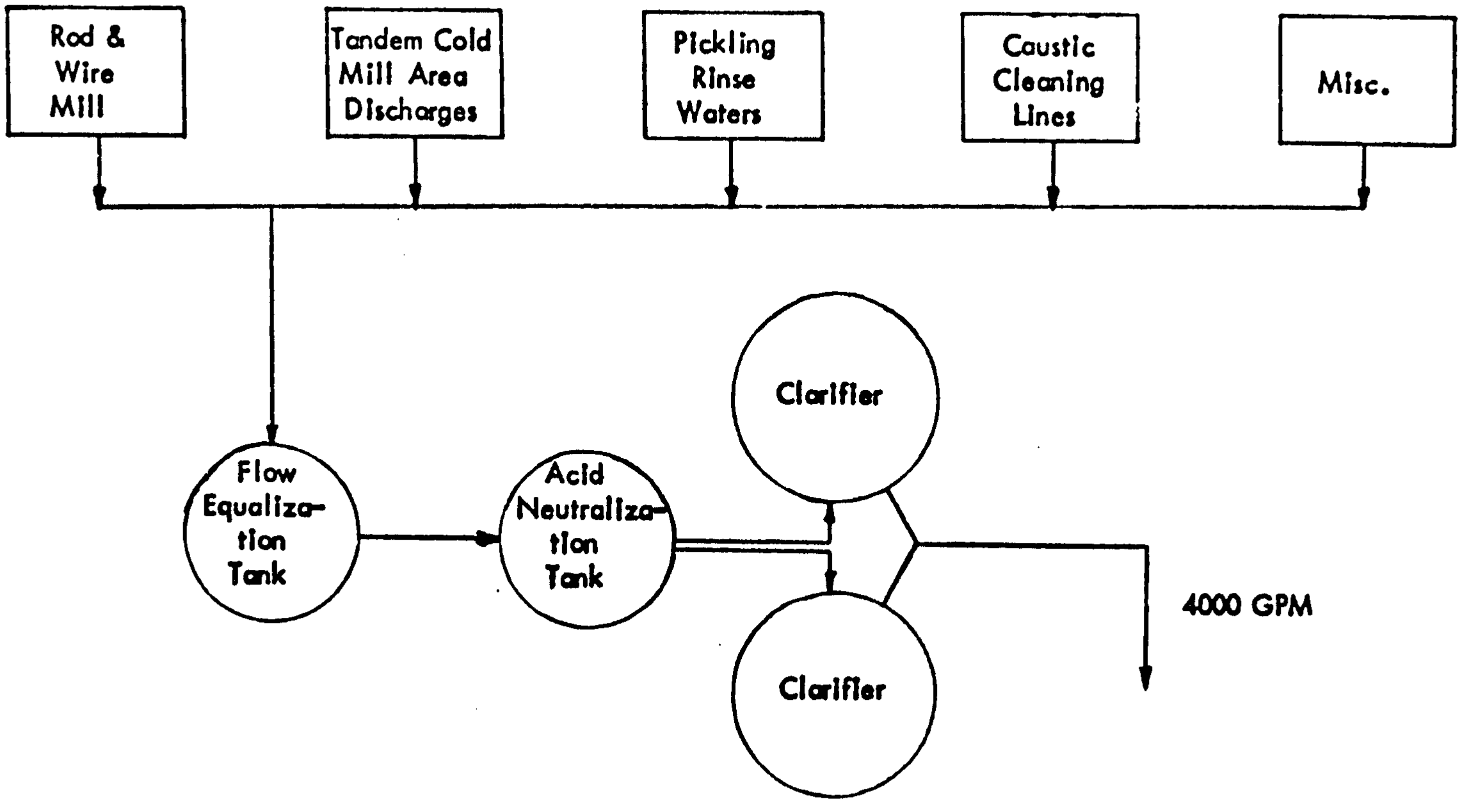


Figure 8-6. COMBINED TREATMENT OF HOT MILL SCALE PIT DISCHARGES

ALIQUIPPA WORKS

ALIQUIPPA WORKS

CHEMICAL RINSE TREATMENT PLANT



Environmental Control Division
November 8, 1976

Figure 8-7. CHEMICAL RINSE TREATMENT PLANT certain scale pits. The second treatment system (Figure 8-7) is a chemical rinse treatment plant to treat discharges from various finishing mill areas. Included are rinse waters from pickling units, blowdown from the tandem cold mill recycle system, caustic cleaning line discharges, tin line rinse waters and miscellaneous sump discharges. Much of the oil collected in this system is disposed of with the sludge from the plant.

NPDES Discharge Monitoring Reports (DMR's) for 1976 were obtained from EPA Region III and reviewed to determine the average daily net oil and grease discharge rate. For the outfalls for which oil and grease discharges are reported, the total net daily average oil and grease discharge was 1478/kg/day (3258 lb/day) or approximately 44,400 l/month (97,800 lb/month).

8.7.4 Other Losses

Significant quantities of oil and grease leave the plant on product intentionally or otherwise. The type of lubricants likely to be found on the product include:

pipe coating oils	582,900 l/yr	(154,000 gal/yr)
cutting oils	579,000 l/yr	(153,000 gal/yr)
thread compounds	44,000 kg/yr	(97,000 lb/yr)
rust preventatives	68,900 l/yr	(18,200 gal/yr)
slushing oils	19,700 l/yr	(5,200 gal/yr)

For material balance estimation it was assumed that 90 percent of these materials leave the plant on the product. The remaining amount would be expected to appear as leaks, be lost in use, or attached to cutting fines.

Mill scales generall contain a significant quantity of oil and grease. These mill scales are currently recycled to the sinter plant where a large portion of the oils and greases are volatized and either condensed and captured by the air pollution control equipment or discharged to the atmosphere. Multiclones are installed and operated to clean the sinter plant waste gas stream and wet scrubbers clean emissions from other sinter plant sources. Most of the volatized hydrocarbons resulting from the recycling of mill scales containing oil are thought to pass through the control devices to the atmosphere. It was reported that 9.1×10^6 kg/month (10,000 tons/month) of mill scales are generated at the Aliquippa Works. Mill scale data from other steel mills indicate that the oil content typically ranges from 0.1 to 2.0 percent. Assuming an average oil content of 1 percent, it is estimated that 90,700 kg/month (200,000 lb/month) of oils are contained on mill scales. It is thought that most of the oil is volatized and emitted to the atmosphere.

Sludges removed at the wastewater treatment facilities contain oils and greases. It was reported that 3.2×10^6 kg/month (3,500 tons/month) of sludges are removed from the wastewater treatment facilities. For material balance development purposes it was assumed, based on data from other steel mills, that the oil content of these sludges is approximately 5 to 10 percent of 159,000 to 318,000 kg/month (350,000 to 700,000 lb/month) of oil. The sludges from the treatment plant which receive scale pit discharges are sold and the remaining sludges are disposed of by landfill methods. The average value, 238,000 kg/month (525,000 lb/month), was used in the material balance estimate.

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during handling and storage;
- oils and greases contained on trash and debris which are collected and sent to a solid waste disposal area;
- quantities volatized, burned or otherwise consumed in use in the various steel making and shaping processes;

- Leaks and spills on to the floor or ground which are generally cleaned up and disposed of.

8.7.5 Material Balance

Using the data presented above, an attempt was made to develop an overall material balance for total oils, greases and hydraulic fluids. The material balance estimate is illustrated in Figure 8-8. For the conversion of volume to weight units for oils, a density of 0.9 kg/l (7.5 lb/gal) was assumed. Shown on the material balance illustration are kg/month values for several terms and an estimate of the percent of the total input represented by each loss term. The estimated loss terms account for 102 percent of all lubricant purchases.

Estimates of the other loss terms (the four terms called out with bullets above) are not included but are expected to account for roughly 10% of the total input. Oils drained, collected and processed by the waste oil scavenger are also not shown on the material balance estimate illustration. It appears, based on data from other mills, that the oil on products and in sludges terms are over estimated. The uncertainty in these and the other loss terms could result in the material balance errors.

8.8 Republic Steel Corporation, South Chicago, Illinois

A summary of the major equipment and products associated with the Republic Steel Corporation, South Chicago Works, is provided in Table 8-12. The information presented in the table is a summary of data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief the steel production capacity at the South Chicago facility is 1.8×10^9 kg/yr (2.0×10^6 tons/yr). During 1975, the year for which lubricant usage data was reported, actual steel production was approximately 1.4×10^9 kg/yr (1.5×10^6 tons/yr).

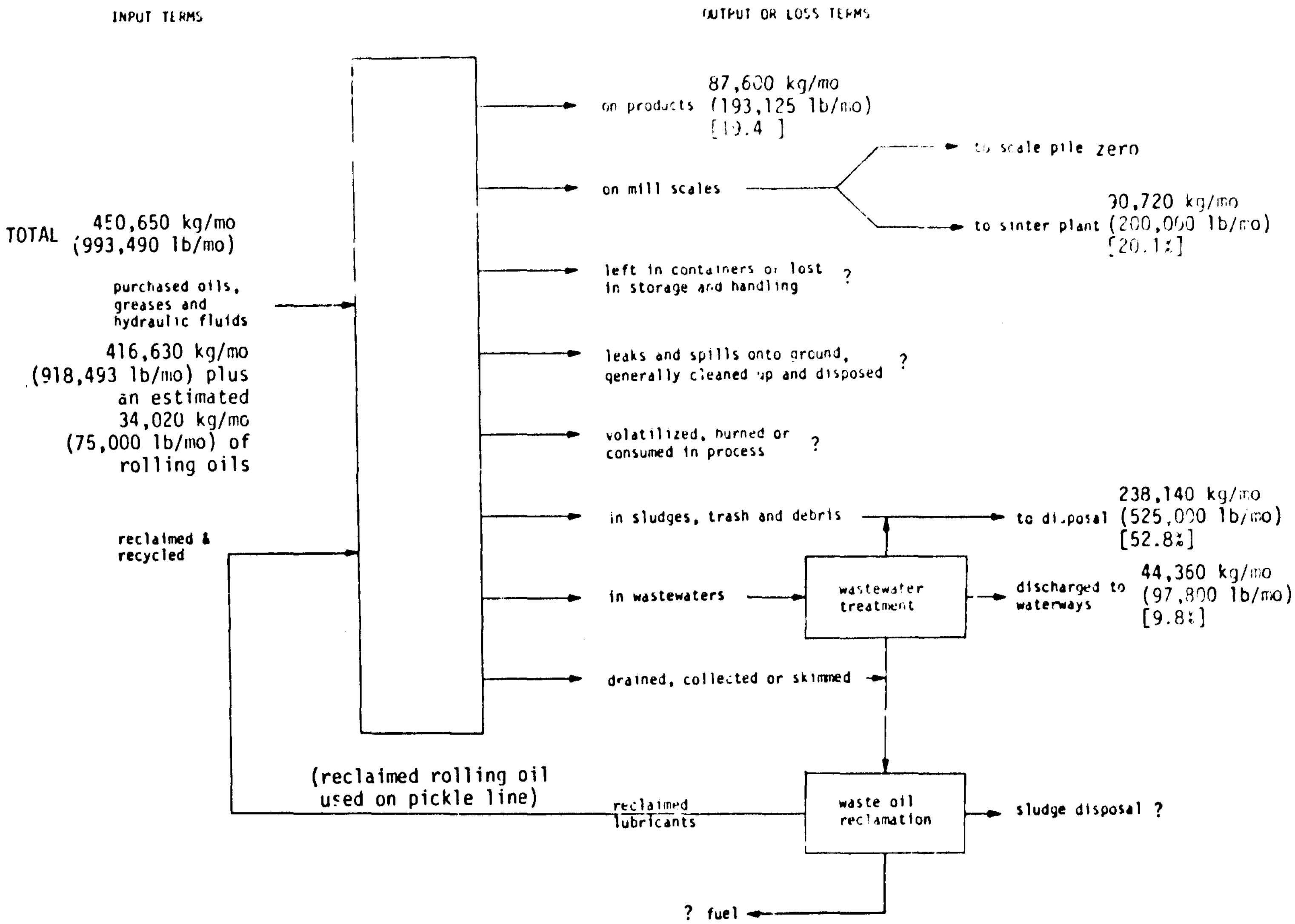


Figure 8-8. MATERIAL BALANCE - JONES AND LAUGHLIN STEEL CORPORATION, ALIQUIPPA

TABLE 8-12. REPUBLIC STEEL CORPORATION - SOUTH CHICAGO, ILLINOIS*

Equipment

75 Coke ovens by-product
1 Blast furnace
4 Basic open hearth furnaces
3 Electric arc furnaces

No.	Type of Mill	Annual Rolling Capacity
1	Blooming	1,860,000
1	Billet	300,000
1	Billet & bar	1,027,000
3	Bar	1,365,000
1	Rod	165,000
7		4,708,000 Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} =$$

$$\frac{0}{4.708 \times 10^6} = 0$$

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works (1.0 ton = 907.2 kg)

8.8.1 Lubricant Purchases

Lubricants, oils, greases and hydraulic fluids purchased during 1975 are listed in Table 8-13 by type, quantity purchased and use. A total of 308,260 kg (679,590 lb) of grease and 1,742,000 l or 1,566,000 kg (460,192 gal or 3,451,440 lb) of oils and hydraulic fluids were reported. Of the 1,742,000 l (460,192 gal) of oils and hydraulic fluid, approximately 1,064,000 l (281,055 gal) (61%) were oils and 678,000 l (179,137 gal) (39%) were hydraulic fluids. It was reported that during 1975 126,500 l (33,425 gal) of fire-resistant hydraulic fluids were used. This represents nearly 20 percent of the total quantity of hydraulic fluids used at the South Chicago Works. A total of approximately 1,874,000 kg (4,131,000 lb) of oils, greases and hydraulic fluids were purchased in 1975 for use at the South Chicago Works.

8.8.2 Reclamation and Treatment

Waste oil recovery and reclamation practices at the South Chicago Works include the reclamation of fire resistant hydraulic fluids by Radco Industries. No other waste oil recovery or reclamation practices were reported. No information regarding sludges generated by Radco Industries was available. However, it is thought that little, if any, sludge is formed. Radco Industries provides fire resistant hydraulic fluid recovery services to the steel and other industries. Excess PCB's are incinerated and a reusable hydraulic fluid is returned to the steel mill.

8.8.3 Discharges to Waterways

Data for 1975 reported by Republic Steel Corporation for three outfalls indicate that about 200 kg/day (443 lb/day or 161,695 lb/yr) of hexane soluble materials are discharged from the South Chicago

Table 8-13. LUBRICANTS, OILS & GREASES USED IN 1975

TYPE	QUANTITY	USE	CATEGORY*
Grease Ryton #2	400 Lbs.	High temp. use and infrequent relubrication on grinders and furnace areas, 14" hot saws and 10" rod mill.	G
ARCO #AWS 315	21,000 Gals.	Anti-wear hydraulic oil on grinders, bar classifier and deburring machine.	HF
Castan [illegible] Supreme Arco Oil	220 Gals.	Locomotive crankcase oil.	O
HD Gear-Arco [illegible] Oil	[illegible] Gals.	[illegible] equipment gearing oil.	O
Arco Pennant NLS [illegible] Oil	115 Gals.	General purpose gear lubricant.	O
Arco Pennant NLS 1000 Bulk Oil	24,310 Gals.	11" Mill C&D oil systems. 11" Mill pinion drive oil systems.	O
Arco Pennant NLS 1000 Drum Oil	10,250 Gals.	Used plant wide for general lube applications.	O
" " " 1500 Oil	220 Gals.		
" " " 2500 Oil	18,480 Gals.		
" " " [illegible] Oil	4,940 Gals.		
Hyd. Pacemaker #20 Citgo Oil	220 Gals.	General use hydraulic oil in T&E and 14" Mill.	HF
Tub " #30 " "	220 Gals.		
Citgo Sentry 70 Oil	25,600 Gals.	B-System and Morgoil System in 11" Mill Finishing.	O
Citgo Sentry 150 Oil	25,500 Gals.	A-System and Morgoil System in 11" Mill Rougher.	O
Motor C-500-10 Citgo Oil	3,030 Gals.	Mobile equipment - crankcase oil.	O
Motor C-520-W-30 Citgo Oil	8,800 Gals.		
Glycol FR [illegible] Citgo Fluid	10,870 Gals.	Straddle Trucks.	HF
Gear Citgo EP90	10,400 Gals.	11" Mill C&D System and pinion system oil.	O
HD Soluble-Continental Oil	5,460 Gals.	Light medium cutting operations.	O
Navajo Valve Continental Oil	1,320 Gals.	Gear reducer oil.	O
Conoco Milgear #160 Oil	25,000 Gals.	Cellar systems in Primary & Tube Mills.	O
Exxon Tremist EP#3 Oil	11,000 Gals.	14" Mill mist system.	O
Endok B Exxon Grease	3,910 Lbs.	Electric motor grease.	G
Gear Imperial #170-W Oil	440 Gals.	Melt Shop cranes. Stripper cranes.	O
Imperial 727-90 Oil	4,180 Gals.	Melt Shop cranes, stripper and soaking pit cranes.	O
Imperial [illegible]-1 Grease	52,795 Lbs.	Pit Cranes.	G
Imperial [illegible]-1 Grease	133,220 Lbs.	Melt Shop and mill cranes.	G
DTE Heavy Med. Hyd. Mobile Oil	5,500 Gals.	Soaking pit O.D. fans.	O
M[illegible] Magic Grease	48,740 Lbs.	General Purpose.	G
Hydroplex #2 Magic Grease	600 Lbs.	14" Mill and Tube Mill-General.	G
Republic [illegible] #3 Magic Grease	3,[illegible] Lbs.	Ore dock bridge and Hullets.	G
Soluble C Magic Cutting RH Oil	4,200 Gals.	Light duty cutting oil.	O
Republic EP #3 Magic Grease	48,000 Lbs.	Tube Mill - general purpose.	G

Table 8-13 (continued) LUBRICANTS, OILS & GREASED [illegible] IN 1975

TYPE	QUANTITY	USE	CATEGORY*
A-2 Magic Oil	1,100 Gals.	Light machine oils used plant wide.	O
A-3 Magic Oil	8,440 Gals.		
A-6 Magic Oil	1,100 Gals.		
A-10 Magic Oil	17,045 Gals.	Machine oils used plant wide.	O
A-12 Magic Oil	330 Gals.		
A-1[illegible] Magic Bulk Oil	13,420 Gals.	10" Mill pinion system.	O
Republic [illegible] Magic Grease	16,810 Lbs.	Tube Mill and Blast Furnace general purpose.	G
Republic [illegible] #00 Magic Grease	2,4[illegible]0 Lbs.	Ore docks and Blast Furnace cold weather grease.	G
Republic [illegible] Magic Grease	47,[illegible] Lbs.	Tube Mill general use.	G
Republic [illegible] #1 Magic Grease	4,[illegible]40 Lbs.	Cranes.	G
Republic [illegible] #2 Magic Grease	3,6[illegible]0 Lbs.		
Turbo #27 [illegible] Oil	1,[illegible] Gals.	Boiler House turbine oil.	O
Omala #8[illegible]-Shell Oil	37,[illegible]0 Gals.	Gear oil for Primary & Tube Mill.	O
Tonna #3[illegible]-Shell Oil	165 G[illegible]s.	Machine Shop oil.	O
Compressor #55[illegible] Aicaid Oil	[illegible]5[illegible] Gals.	Air compressors.	O
Regal FA[illegible] [illegible] Grade Texaco Oil	2,0[illegible]0 Gals.	Waste heat blowers and Boiler House blowers.	O
Texmatic [illegible]534 Texaco Fluid	3,650 Gals.	Mobile equipment transmission fluid.	O
Regal R&O-E Grade Texaco Oil	5,390 Gals.	Boiler House and waste heat blowers.	O
Hyd Rando A #1643 Texaco Oil	12,114 Gals.	General purpose hydraulic oil.	HF
Hyd Rando C #1648 Texaco Oil	7,718 Gals.		
Hyd 735 Texaco Oil	2,7[illegible] Gals.	10" Mill Escania system.	HF
[illegible]0 Texaco Crater-Compd. Grease	2,4[illegible] Lbs.	Cranes.	G
#1X Texaco Crater Compd. Grease	4,0[illegible]0 Lbs.	Open gear applications. Plant wide use.	G
#5X Texaco Crater Compd. Grease	2,730 Lbs.		
#5X Texaco Fluid Grease	490 Lbs.		
Texclad #2 Texaco Grease	2,400 Lbs.		
Klingfast #[illegible]70 Brooks Grease	4,920 Lbs.		
Flexalene #725 [illegible] Grease	189,40[illegible] Lbs.	General purpose - plant wide.	G
Houghto-Safe #1120 Lubricant	330 Gals.	General plant use.	O
Houghto-Safe #520 Lubricant	14,860 Gals.	Water glycol fluid for 36" and 34" Mill area.	HF
Fydraul 50E Monsanto Lubricant	660 Gals.	Fire resistant for Coke Plant, Blast Furnace and Melt Shop.	HF
Fyrquel #220 Oil Star Lubricant	165 Gals.	Stripper crane fire resistant hyd. fluid.	HF
Pydraul [illegible] Monsanto Lubricant	29,[illegible] Gals.	Fire resistant hyd. fluid.	HF
Pydraul 29 ELT. Monsanto Lubri.	3,960 Gals.	Hyd. fluid, various applications.	HF
Magic M-[illegible] Grease	48,0[illegible]0 Lbs.	Plant general.	G
Magic [illegible] Grade 0,1,&2 Grease	36,000 Lbs.	Gear case grease.	G
Brooks [illegible] Flexalene 725 - MO Grease	25,000 Lbs.	Cooling beds.	G
Shell #33 Hyd. Oil	36,[illegible]0 Gals.	Tube Mill hydraulic oil.	HF
[illegible] 6[illegible] 31 Hyd. Oil	36,[illegible]0 gals.	Tube Mill hydraulic oil.	HF
Monsanto Chemical Hydraul 29 ELT or 50E	4,000 Gals.	Fire resistant hydraulic fluid for Electric Furnace.	HF

Note: O- Oil G- Grease HF- Hydraulic Fluid
(1.0 gal = 3.785 l and 1.0 lb = 0.4536 kg)

Works. A total oil and grease discharge rate estimate was also made by using NPDES Permit Application information. If all four outfalls were discharging wastewaters (only three are reported to have a net total oil and grease discharge), with the average net oil and grease content and at the average flow rate indicated in the permit application, the total oil and grease discharge would be 360 kg/day (792 lb/day or 289,080 lb/yr). This would represent about 7 percent of the oils, greases and hydraulic fluids used in the plant.

8.8.4 Other Losses

Significant quantities of oils and greases are applied to steel products intentionally or during processing. The quantity of lubricants and rust preventatives leaving the Republic Steel, South Chicago plant on products could not be determined because no data was available from the steel mill. It is expected that a significantly lower quantity of oil leaves the South Chicago Works on products, compared to other steel mills in the study, since only bar, rod, tube and wire products are shipped. Large quantities of coating and slushing oils are generally associated with rolled strip, sheet or coiled steel products. From data and estimates of quantities of oils on products provided by other steel mills, it is thought that approximately 5 percent of the total oil and grease input to the South Chicago Works leaves on products.

Mill scales collected in the various scale pits also contain oils and greases. Oil contents of mill scale as high as 25 percent by weight have been reported for some rolling mills, although an oil content ranging from 0.1 to 2.0% is typical. Mill scales are generally either stockpiled (often because of excessive oil content which would result in air pollution control equipment or opacity problems) or recycled to a sinter plant or directly to the melt shop. Republic Steel reported that at the South Chicago Works approximately 7.26

x 10^6 kg/month (8,000 tons/month) of scale is removed from scale pits. All mill scale is returned directly to the melt shop for use in the steel making process. No oil content data was available from Republic Steel. For material balance estimation purposes, it was assumed that the average oil content of these mill scales was 0.2 percent. A relatively low oil content value was chosen in consideration of the types of mills operated. Therefore, approximately 14,500 kg/month (32,000 lb/month) of oils are contained on mill scales and subsequently combusted or volatized in the melt shop. No data on the quantity of hydrocarbons emitted to the atmosphere by volatization of these oils was available. It is thought that nearly all of the oil on mill scales fed to the melt shop is combusted.

Sludges and filter cake containing oils and greases generated in wastewater treatment facilities represent a potentially significant loss term. The quantity of filter cake generated at the South Chicago Works wastewater treatment plant was reported to be 10.2 x 10^6 kg/yr (11,295 tons/yr) during 1976. The oil content of this filter cake was unknown. Sludges and filter cake are reportedly stockpiled by Republic Steel. Assuming an average oil content of ten percent, which is typical for filter cake and sludges generated at other steel mills, it was estimated that 85,400 kg/month (188,250 lb/month) of oil is lost in this manner.

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during handling and storage;
- oils and greases contained on trash and debris which are collected and sent to a solid waste disposal area;
- quantities volatized, burned or otherwise consumed in use in the various steel making and shaping processes;
- leaks and spills on to the floor or ground which are cleaned up and disposed of.

No data was available from Rerublic Steel regarding these various loss terms.

8.8.5 Material Balance

Using the data and estimates presented above, an attempt was made to develop an overall material balance for total oils, greases and hydraulic fluids. The material balance estimate is illustrated in Figure 8-9. For the conversion of volume to weight units for oils, a density of 0.9 kg/l (7.5 lb/gal) was assumed. Shown on the material balance illustration are kg/month values and the percent of the total input represented by each loss term for which data was obtained. PES was able to account for 76 percent of the total oil, grease and hydraulic fluid input to the South Chicago plant. The four miscellaneous loss terms, noted above with bullets, are thought to account for roughly 10 to 20 percent of the total input. Uncertainty in the estimated loss terms; such as oil on product, on mill scale or on sludges, may account for the remainder of the input.

8.9 Interlake, Inc., Riverdale, Illinois

A summary of the major equipment and products associated with the Interlake, Inc., Riverdale facility, is provided in Table 8-14. The information presented in the table is a summary of the data provided in the AISI Directory of Iron and Steel Works. According to the IISS Steel Industry in Brief the steel production capacity at the Riverdale Plant is 0.8×10^9 kg/yr (0.9×10^6 tons/yr). During 1975 the actual production is estimated to be 0.5×10^9 kg/yr (0.6×10^6 tons/yr).

8.9.1 Lubricant Purchases

Lubricant usage data reported by major plant area is presented in Table 8-15. A total of 92,700 kg/yr (204,340 lb/yr) of grease,

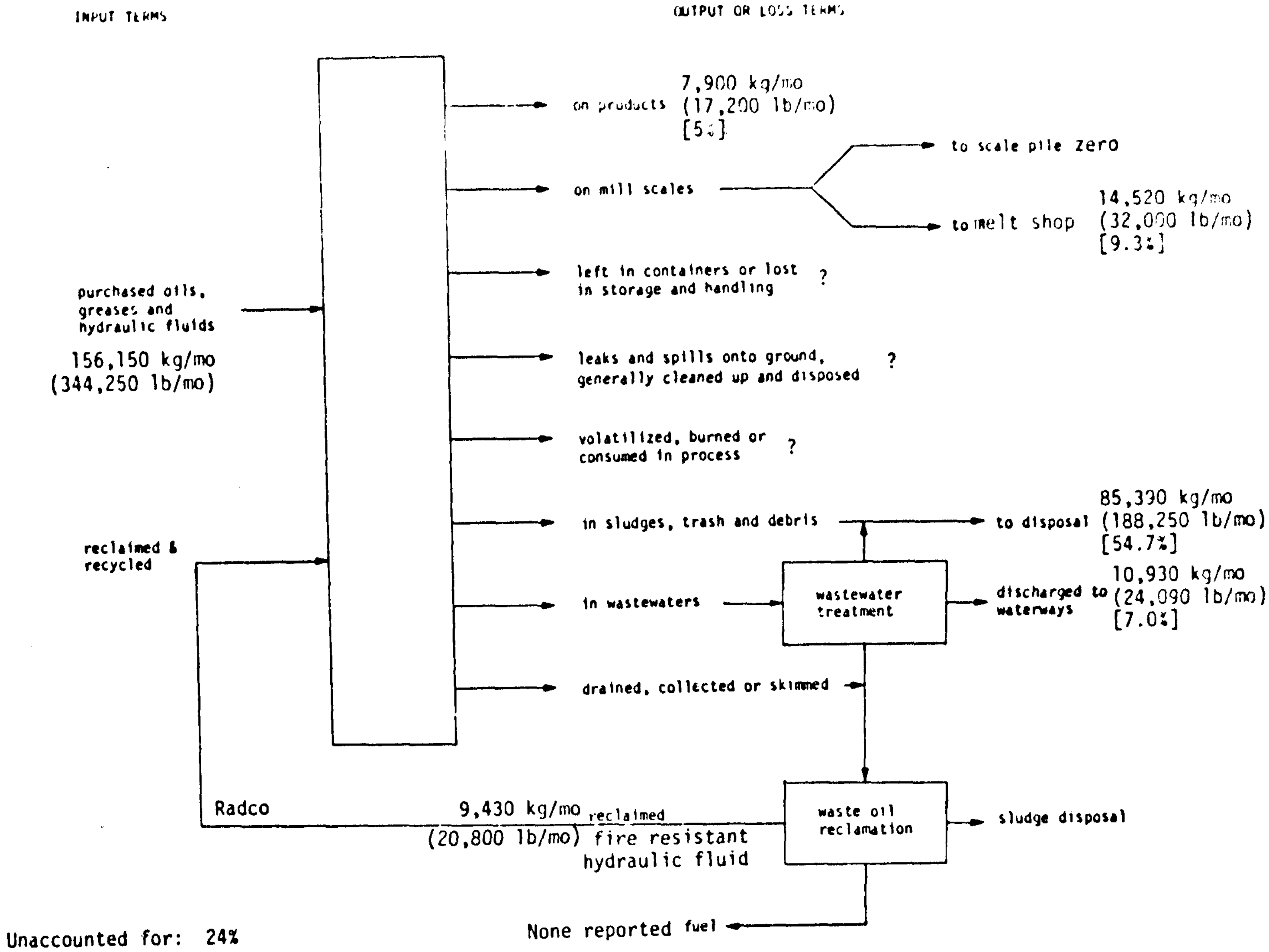


Figure 8-9. MATERIAL BALANCE - REPUBLIC STEEL CORPORATION, SOUTH CHICAGO

TABLE 8-14. INTERLAKE, INC. - RIVERDALE, ILLINOIS*

Equipment

2 Basic oxygen process furnaces

No.	Type of Mill	Annual Rolling Capacity	
1	Primary	737,000	1,317,000 Net Tons
1	Billet	580,000	
2	Hot strip	744,000	1,258,800 Net Tons
5	Strip - cold reducing	254,600	
6	Strip - cold finishing	243,000	
1	Strip - cold sizing	6,900	
16		2,575,800	NET TONS

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} =$$

$$= \frac{1.2588 \times 10^6}{2.5758 \times 10^6} = .49$$

*Equipment and annual rolling capacity data from AISI Directory of Iron and Steel Works

1.0 ton = 907.2 kg.

Table 8-15. LUBRICANT USAGE DATA

Department	Greases	Oils
Melt Shop (2 BOF's)	11,000 lb/yr	1,800 gal/yr
Primary Mills	89,000 lb/yr	43,000 gal/yr
Hot Scrip Mills - 2	5,860 lb/yr	100,000 gal/yr
Cold Mills -	98,000 lb/yr	138,000 gal/yr + 6,000 gal/yr rolling oil
Pickling Line	480 lb/yr	115,000 gal/yr

Total	
Greases	204,340 lb/yr
Lube Oils	397,800 gal/yr
Rolling Oils	6,000 gal/yr

Note:

(1.0 gal = 3.785 l)

(1.0 lb = 0.4536 kg)

150,600 l/yr (397,800 gal/yr) of lube oils and 22,700 l/yr (6,000 gal/yr) of rolling oils are utilized. Assuming 0.9 kg/l (7.5 lb/gal) for the lube and rolling oils, the total oil and grease input to the plant is 1,466,000 kg/yr (3,232,800 lb/yr). No information is available on purchases of hydraulic fluids and process oils.

8.9.2 Reclamation and Treatment

Waste oil recovery efforts include collecting oils from the cold mills and pickup by a waste oil scavenger. A 10 percent oil in water emulsion is recirculated in the mills. When the emulsion reaches 6 percent oil in water it is disposed of by cracking the emulsion with waste pickle liquor. The recovered waste oil is applied to in-plant dirt roads to suppress dust. Consideration is being given to sending this waste oil to the coke ovens where it can be used to replace straw oil which is currently used as a bulk density control for coal being coked.

Consideration is being given to phasing out the belt skimmers installed on scale pits and replacing them with more effective Lockheed "Clean Sweeps."

8.9.3 Discharges to Waterways

The water system at the Riverdale plant includes total separation of process water, which is recycled except for a small amount of blowdown, and cooling and storm water, which is discharged to the Little Calumet River.

Three wastewater treatment facilities are operated. They are the:

1. basic oxygen furnace clarifier system
2. sand filtration system on the #4 hot-strip mill
3. Neutralization-oxidation system for treating spent acids (waste pickle liquor).

The sand filtration system is of interest to this study because it is designed to treat and recycle all contact process water used on the #4 hot-strip mill. The system's major components are six sand filters each rated at 9,500 l/min (2500 gal/min), a backwash surge tank, a 12m (40-ft) diameter by 3.6m (12-ft) side wall depth clarifier, a 3m (10 ft) by 3m (10 ft) vacuum filter with ancillary equipment, and a recycle pump house. Suspended solids and oils are removed by the system. Operational data are as follows:

	Influent to System	Effluent from System
Flow	37,850 lpm (10,000 gpm)	37,850 lpm (10,000 gpm)
Suspended Solids	250 ppm	30 ppm
Oil	50 ppm	15 ppm

From the influent and effluent data it was estimated that 1900 kg/day (4200 lb/day) of oil is captured in the sand filters. It was reported that an off-site waste oil reprocessor reclaims this oil as a motor oil. No information could be provided on the oil discharges from the process water recycle system blowdown.

8.9.4 Other Losses

Mill scales collected in the two hot-strip mills and the primary mill scale pits are recycled to a sinter plant. Oils and greases contained on the mill scale are volatized during sintering.

A wet precipitator is installed and operated on the sinter plant. The volatized oils and greases cause a bluish haze, possibly due to the condensible hydrocarbons. Source test data, described during an interview with Fred Krikau, Director of Environmental Control at the Interlake Riverdale plant, indicate that about 37 kg/hr (81 lb/hr) of total hydrocarbons are present in the sinter plant stack gas prior to the wet precipitator. The wet precipitator outlet gases contain 1.8 kg/hr (4 lb/hr) of total hydrocarbons. Research into de-oiling mill scale with solvents proved ineffective because the solvents actually added to the hydrocarbon air pollution problem.

Significant quantities of oils and greases are applied to steel products intentionally or during processing. No estimate was provided of the quantity of oils and greases leaving the Interlake plant on products. Also, no estimate was provided for the oil and grease content of sludges removed at the wastewater treatment facilities.

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during handling and storage;
- oils and greases contained on trash and debris which are collected and sent to a solid waste disposal area;
- quantities volatized, burned or otherwise consumed in use in the various steel making and shaping processes;
- leaks and spills which are cleaned up and disposed of or leak into the ground.

8.9.5 Material Balance - Detailed information on lubricant usage and fate could not be obtained for the Riverdale facility and a complete material balance estimate could not be prepared. Available material balance information is summarized below. Of the total input of 122,200 kg/month (269,400 lb/month), approximately 23 percent is contained on mill scales. It was estimated from limited sinter plant source test data that 1330 kg/month (2880 lb/month) (1.1 percent of the total steel mill oil and grease input) is emitted from the sinter plant stack. Approximately 26,450 kg/month (58,320 lb/month) of oil (21.6 percent of the total input) is captured by the wet precipitator.

The sand filtration system on the #4 hot-strip mill is estimated to collect 57,000 kg/month (126,000 lb/month) 46.8 percent of the total input) of oil and grease, which is reclaimed as motor oil by an off-site reprocessor.

The remaining 30 percent of the oils and greases that are inputted to the plant are unaccounted for. Wastewater discharges are expected to account for a portion of the oil and grease input. The quantity of oils and greases on products, left in containers or lost in handling and storage, on trash and debris to solid waste disposal, and volatized or consumed in process are expected to account for the remainder.

8.10 Kaiser Steel Corporation, Fontana, California

A summary of the major equipment and products associated with the Kaiser Steel Corporation plant in Fontana, California, is provided in Table 8-16. The information presented in the table is a summary of the data provided in the AISI Directory of Iron and and Steel Works. The production capacity of the Fontana plant is approximately 3.3×10^9 kg/yr (3.6×10^6 tons/yr). Six of the open hearth furnaces are being decommissioned and Kaiser is currently replacing this steelmaking capacity with two new basic oxygen furnaces. Two open hearth furnaces will be retained for handling scrap. The actual production rate for 1975 and 1976 was reported to be about 70 percent of capacity or 2.3×10^9 kg/yr 2.5×10^6 tons/yr).

Table 8-16. KAISER STEEL CORPORATION - FONTANA, CALIFORNIA*

EQUIPMENT

315 Coke ovens - by-product
4 Blast furnaces
8 Basic open hearth furnaces**
3 L-D oxygen process furnaces

No.	Type of Mill	Annual Rolling Capacity	
1	Slab	3,120,000	4,368,000 Net Tons
1	Blooming	1,248,000	
1	Plate	824,000	6,019,000 Net Tons
1	Structural	457,000	
1	Merchant skelp	333,000	
1	Hot-strip	1,500,000	
2	Reversing	316,000	
2	Cold reducing	820,000	
3	Skin pass	571,000	
3	Temper	1,198,000	
16		10,387,000	Net Tons

$$\frac{\sum \text{Capacities of hot strip, cold rolling, cold finish \& temper mills}}{\sum \text{Capacities of all primary and secondary mills}} = \frac{4.405 \times 10^6}{10.387 \times 10^6} = .42$$

*Equipment and annual rolling capacity data from AISI <u>Directory of Iron and Steel Works</u> (1.0 ton = 907.2 kg).

**Two 200 metric ton/heat (225 ton/heat) basic oxygen furnaces (BOF) will replace six of the open hearth furnaces (OH). Two open hearth furnaces will be maintained and used for scrap steel processing. The blooming mill, structural mill and merchant-skelp mill will be decommissioned in late 1977.

Table 8-17. KAISER STEEL CORPORATION, FONTANA PLANT

OILS, GREASES AND HYDRAULIC FLUIDS PURCHASE DATA

Lubricant Type	Quantity Purchased*	
	Pounds	Gallons
Greases - All Products	1,452,331	
Open Gear Greases & Chain Oils	10,491	39
Gear Oils		434,061
Circulating Oils & Mist Oils		455,785
Hydraulic Oils		180,242
Turbine & Air Compressor Oils		24,915
Motor Railroad & Transmission Fluids		50,539
Cutting & Grinding Oils & Compounds & Soluble Hydraulic Fluids	1,962	92,531
Miscellaneous Products	7,170	54,847
Process Oils & Metal Protective Coatings		2,175
Rollings Oils & Fats	1,560,000	
TOTALS	3,032,540 lb	1,355,134 gal.

*Based on Kaiser Steel Corporation purchase records for the period of July 1, 1975 to June 30, 1976. Fuels, solvents and coke plant wash and spray oils are not included. These purchase data include materials purchased for and consumed by the Metal Products Division.

(1.0 gal = 3.785 l and 1.0 lb = 0.4536 kg)

8.12.1 Lubricant Purchases

The Lubrication Department of the Kaiser Steel Corporation plant in Fontana provided a very detailed tabulation of the types and quantities of lubricating oils, greases, and hydraulic fluids purchased during the third and fourth quarters of 1975 and the first and second quarters of 1976. The application or usage of the lubricants and hydraulic fluids, as well as the type and size of container in which the material was purchased, was reported. The purchase records are very detailed and include specialty products purchased in small quantities. It is thought that the Fontana plant data are more comprehensive than that obtained from other steel mills in the survey, and, as a result, the total quantity of lubricants and hydraulic fluids may appear larger than would be the case if determined or estimated in a manner similar to some of the other mills. The lubricant purchase provided by Kaiser Steel includes some materials purchased for and consumed by the Metal Products Division, a satellite operation located adjacent to the Fontana steel mill. The Metal Products Division, which includes light steel, structural steel and plate steel fabrication facilities, are estimated to consume roughly 5 to 10 percent of the lubricant stocks purchased by the Fontana plant. Note also that purchase records during a one year period may differ from the actual quantity of lubricants or hydraulic fluids used.

Lubricant usage data which are summarized by general type of oil, grease or hydraulic fluid are presented in Table 8-17. A total of 310,400 l/yr (1,174,892 gal/yr) of lubricating and process oils was purchased during the one year period from July 1, 1975 to June 30, 1976. In addition, about 707,000 kg/yr (1,560,000 lb/yr) of rolling oil and fats was bought. The total quantity of grease purchased during that time period was 668,000 kg/yr (1,472,504 lb/yr).

while the quantity of hydraulic fluids purchased was 682,000 l/yr (180,242 gal/yr). Assuming an average density of 0.90 kg/l (7.5 lb/gal) for oils and hydraulic fluids, the total average quantity of oils (including rolling oils) greases and hydraulic fluids used was approximately 499,000 kg/month (1,101,000 lb/month).

8.13.2 Reclamation and Treatment

Waste oil recovery efforts include the use of oil skimmers on some scale pits and a float-sink tank in the wastewater treatment plant. The Lubrication Department has been investigating the potential for reclaiming these waste oils skimmed in the plant and returning them as gear oil or general purpose mill oils. To date an over-the-fence reclaimer has successfully returned about 76,000 liters (20,000 gal) of gear oil reclaimed from waste oils collected at the Fontana Plant. The reclamation of waste oils as fuel oils is an additional alternative. This practice has also been employed by Kaiser Steel. Current plans are for the continued and increased use of outside waste oil reclaimers to return valuable lubricants to the mill from collected waste oils.

Kaiser Steel is also investigating ways of enhancing waste oil recovery capabilities by installing additional oil skimmers and segregating waste oils and collecting them at their sources. This will simplify reclamation efforts and maximize the return as lubricants rather than fuel oil. A use or reclaimer for fats and oily scums collected at the treatment plant float-sink tank is also under investigation by Kaiser Steel.

To reduce the usage of lubricants and cut down on the resulting waste oil load, the Lubrication Department has taken and is considering a number of measures. To reduce the frequency of leaks, the oil and grease lines in the hot strip mill are being rebuilt. Improved lubrication systems and maintenance practices are also being reviewed. The existing hot strip mill lubrication system for the mill table bearings are being replaced by a more effective mist oil system. The conversion of the hot strip mill lubrication system is about 80 percent complete at this time. This two-step approach, that of reducing lubricant usage and losses while increasing waste oil collection capabilities, is being pursued by the Lubrication Department as time and funds permit.

8.10.3 Discharges to Waterways

Water usage and treatment at the Fontana plant is unique and calls for a brief description. Their water system is recognized as having the tightest water recirculation systems currently operating at an integrated iron and steel plant; they have nearly zero water discharge. The general concept applied at Kaiser Steel for water usage, recirculation and waste treatment is that water passes through a number of systems in series, with the blowdown of one system becoming the supply of the following system. The systems are sequenced in order of quality requirements, with the first system having the highest quality and the last system the poorest. The point is reached where water quality deterioration is such that it can no longer be used in any system and then it is disposed of in final uses, such as slag quenching, sinter cooling, BOF hood sprays, etc. A small quantity of excess water is discharged to the non-reclaimable waste water line managed by the local municipality which treats it and ultimately discharges it to the ocean. Oils not captured by oil skimmers which reach the waste water treatment plant are removed by float/sink separator and clarifier. Since most waters are recycled and eventually evaporate as quench sprays, very little oil is discharged from the Fontana plant in wastewater. Final use waters are reported to contain an average of about 200 mg/l of oil. At an estimated average flow of 1500 l PM (400 GPM) to absolute terminal uses, it was estimated that 13,000 kg/month (28,800 lb/month) of oil are contained in quench waters. When these waters are sprayed on slag, BOF hoods, or used for sinter cooling the oils are volatized and lost to the atmosphere.

NPDES data indicate that only after significant periods of rain are oils discharged in run-off. It was estimated that about 6800 kilograms (15,000 lb) of oil were discharged during periods of run-off during 1976. A limit of 15 mg/l of oil in the run-off is permitted. A detention pond designed to handle the 10-year intensity rainfall is being installed to eliminate most water discharges resulting from rainfall. The pond will be equipped with an oil skimmer for recovery of the oils contained in captured run-off.

8.10.4 Other Losses

Mill scales collected in the various scale pits also contain oils and greases. Data provided by Environmental Quality Control Department at the Fontana plant, concerning a 1971 study of mill scale quantities, was used to estimate the amounts of oil in mill scale and their fate. Oily mill scales are currently stockpiled for future recovery due to potential air pollution control equipment and opacity problems which would result from the volatized oils.

The sinter plant is equipped with a baghouse for air pollution control. Fouling of the bags or opacity problems are encountered if mill scales are sintered. Large differences in the oil content of mill scales collected in various scale pits was noted in the 1971 study. For example, the oil content of mill scales taken from hot-strip mill scale pits ranged from 0.4 to 23.5 percent, averaging 5 to 10 percent by weight. Slab mill, blooming mill, continuous weld pipe mill, merchant mill and structural mill scales all contain less than 1 percent oil. From the data and discussions with Kaiser Steel personnel, it was estimated that a total of 171,100 kg/month (377,200 lb/month) of oil are contained on mill scales. All of this oil is contained on mill scales which are stockpiled. Preliminary investigations have been made by Kaiser Steel into alternative methods of removing and handling mill scales from the scale pits. One possible approach is to hydraulically pump the mill scales to a central mill scale treatment facility where the oils would be removed with a solvent. This system would enable the recycle of mill scales, after drying, directly to the blast furnace. The feasibility of recovering the oils from the mill scales and reclaiming them as a fuel might also be achieved.

Significant quantities of oils and greases are thought to leave a steel mill on the products. Oils and greases become attached to the steel during rolling. These oils are generally removed prior to the application of metallic coatings, such as tin plate and galvanizing, and are carried away in wash and pickle liquors. Oils are applied to some products intentionally for rust prevention purposes. The only information concerning this practice at the Kaiser plant indicates that about 34,000 to 38,000 liters (9,000 to 10,000 gal) of metal protective oils were applied during the period of which lubricant data was provided. The actual quantity of oils and greases contained on products is thought to be larger than this value. Oils finding their way onto products, such as pipe products, during production often result in a residual quantity which leaves the plant. Applied and residual oils on products are estimated to be about 56,800 l/yr (15,000 gal/yr) or nearly 4,540 kg/month (10,000 lb/month).

Sludges generated in various areas of the plant and by the waste oil reclaimer handling Fontana plant waste oils contain oils and greases. Sludges from the wastewater treatment plant are being mixed with the coking coal and being charged to the coke ovens. This practice is expected to continue until an alternative use or recovery method is found. The quantity of sludges and oil content of these sludges was not reported by Kaiser Steel. Data at other steel mills indicate that oil contents of 5 to 10 percent are typical and therefore the oil in sludge loss term can represent a considerable portion of the total quantity of lubricants and hydraulic fluids used at the steel mill.

Other loss terms identified in the oil, grease and hydraulic fluid material balance include:

- amounts left in containers or lost during storage and handling;
- quantities volatized, burned or otherwise consumed in use in the various steel making and shaping processes;
- leaks and spills on the floor or ground which are generally cleaned up and disposed of.

Quantitative data for these miscellaneous loss terms is very difficult, if not impossible, to obtain and could not be provided by the steel mill. It was estimated that as much as 10 percent of some greases are left in containers and lost. A lower quantity of oils would be expected to be lost in containers. Efforts to reduce the frequency of leaks and spills are continually practiced at the Fontana plant, as described previously. It is estimated that about 20 percent of all oils, greases and hydraulic fluids are lost via these three miscellaneous terms.

8.10.5 Material Balance

A material balance estimate for the Fontana plant was developed from the data obtained in response to a PES questionnaire, information noted during plant visists and telephone discussions, discharge data obtained from EPA Region IX NPDES files, and knowledge of the fate of lubricants gained from other steel mills. This material balance is presented in Figure 8-10 with kg/month and relative percentages of the total input represented by each loss term. A value of 0.9 kg/l (7.5 lb/gal) was used to convert volume to weight units for oil.

The data and estimates provided by Kaiser Steel are indicated in Figure 8-10. PES estimated other values based on information and conclusions drawn from other mills. The Kaiser Steel data estimates account for about 45 percent of the total input. The quantity of oils, greases and hydraulic fluids that are unaccounted for were distributed by PES as follows:

- in sludges, trash and debris, 35 percent;
- left in containers or lost in storage and handling, 5 percent;
- leaks and spills on the floor or ground which are generally cleaned up and disposed of, 5 percent;
- volatized, burned or consumed in use, 10 percent.

Of the 35 percent in sludges, trash and debris, some are disposed of in landfill, while sludges from the wastewater treatment plant are dripped on the coal belts feeding the coke ovens. These oils are burned in the coke ovens.

8.11 Lubricant Usage Data Supplied by Lykins

Joseph Lykins provided data on lubricant usage in a variety of formats. Based on his experience in the steel industry and as a consulting steel mill lubrication engineer, Lykins provided PES with four items regarding lubricant usage. The yearly consumption of various types of lubricants, oils, greases and hydraulic fluids were estimated for a fully integrated steel mill producing three million net tons of steel per year, (see Table 8-18). Using a value of 0.9 kg/l

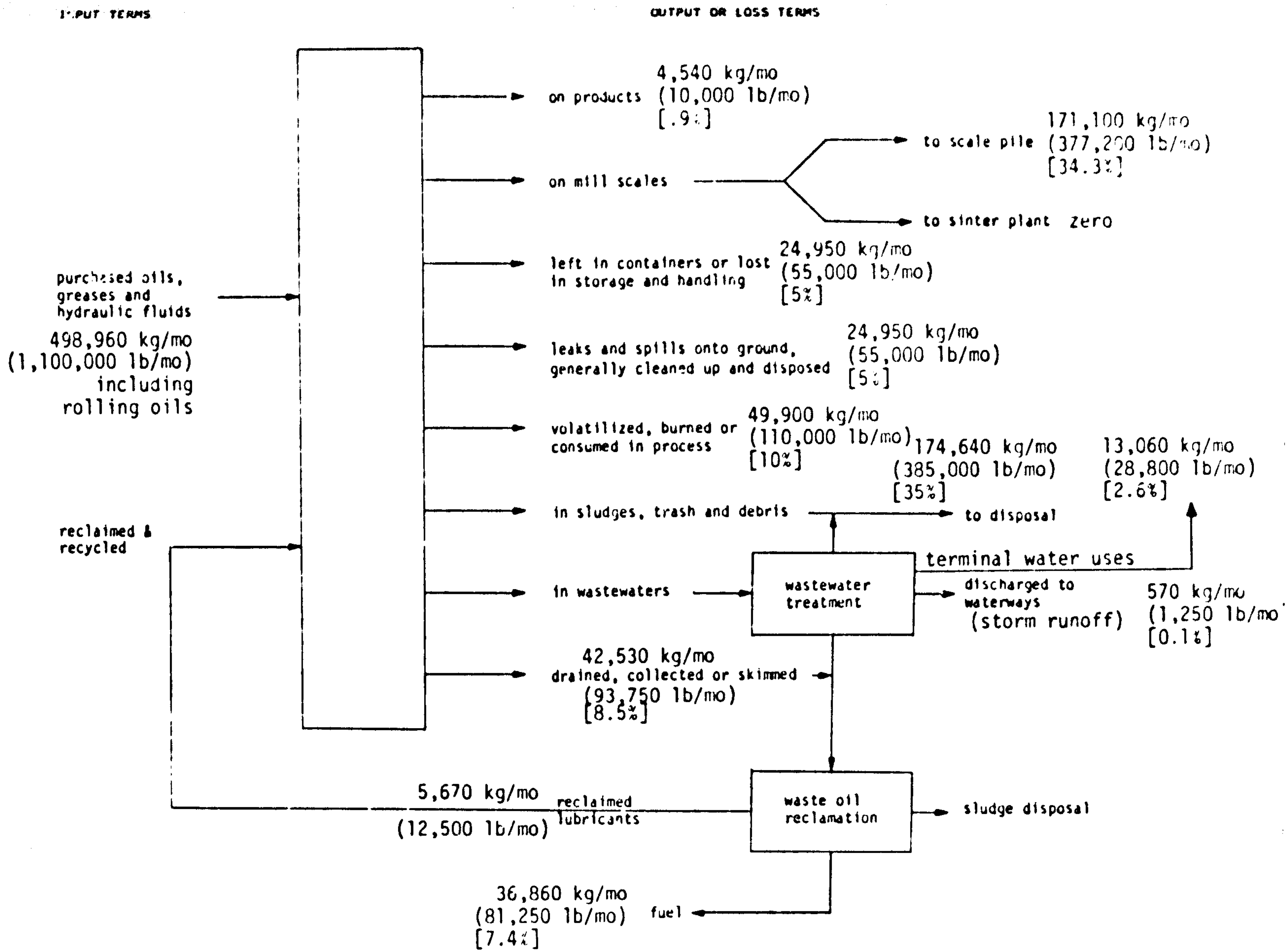


Figure 8-10. MATERIAL BALANCE - KAISER STEEL CORPORATION, FONTANA

Table 8-18

Estimated Yearly Consumption of Lubricants, Oils, Greases and Hydraulic Fluids for a Fully Integrated Steel Mill Producing Three Million Net Tons of Steel per Year.

<u>Oils</u>	
EP Gear Oils	434,000 lb
Rust & Oxidation Inhibited Oils	205,000 gal
Black Oils	6,000 gal
Red Engine Oils	11,000 gal
Motor Oils	100,000 gal
Water Soluble Oils (neat)	120,000 gal
Rolling Oils	6,700,000 lb
<u>Hydraulic Fluids</u>	
Anti-wear Hydraulic Oils	270,000 gal
Inverted Emulsions	165,000 gal
Water - Glycol	140,000 gal
Phosphate Ester Type	35,000 gal
<u>Greases</u>	
Black Lithium & Aluminum Complex Greases	1,400,000 lb
Premium Ball & Roller Bearing Grease	25,000 lb
Specialty Greases	50,000 lb

(1.0 gal = 3.785 l and 1.0 lb = 0.4536 kg)

(7.5 lb/gal) to convert the quantities expressed as liters (gallons) to kilograms (pounds), it is estimated that a total of 7,484,000 kg/yr (16,499,000 lb/yr) of oils, greases and hydraulic fluids are required by an integrated steel mill of the specified capacity. A total oil, grease and hydraulic fluid usage rate of 2.75 kg/1000 kg (5.5 lb/ton) of steel produced was calculated from Lykins' estimate. Table 8-19 summarizes the individual usage of oils, greases and hydraulic fluids per quantity of steel produced per month.

Lykins also provided usage and production rate data for typical rolling and finishing operations. The total quantity of lubricants consumed and corresponding production rate data for 1975 were used to calculate the kg/1000 kg (lb/ton) usage factor for several mills or processes. These data are presented in Table 8-20, which includes only lubricating oils, greases and hydraulic fluids. Usage rates of rolling oils and process oils are tabulated in Table 8-21. The total quantity of lubricants, oils, greases and hydraulic fluids, including rolling and process oils, is 8,430 kg (18,584,845 lb), as summarized in Table 8-22. This usage rate corresponds to a total steel production rate of 2.97×10^9 kg/yr (3,277,000 tons/yr). A value of 2.83 kg/1000 kg (5.67 lb/ton) is obtained by dividing the usage data by the production rate. This value is in the close agreement with the 2.75 kg/1000 kg (5.5 lb/ton) value estimated with the data in Table 8-19.

In addition to the usage and consumption data, and estimates previously presented and discussed in this section, Mr. Lykins supplied PES with a "Practical Guide for Lubricating a Fully Integrated Steel Mill." A copy of this guide is included as Appendix C of this report. For the major steel mill equipment and processes, the types of lubricants and their properties are specified. This information is useful for identifying typical lubricant applications in an integrated steel mill.

Table 8-19

Lykin's Usage Estimates*

	Usage per Ton of Steel	Usage per Month
Oils (includes lubricating and process oils	0.464 gal/T	116,100 gal
Hydraulic Fluids	0.203 gal/T	50,833 gal
Greases	0.492 lb/T	122,917 lb

* 7.5 lb/gal used to convert gallons to pounds.
(0.9 kg/l used to convert liters to kilograms)

(1 gal/ton = 4.172 l/1000 kg)

(1 lb/ton = 0.500 kg/1000 kg)

TABLE 8-20

COMPARISON OF STEEL PRODUCTION AND LUBRICANT AND HYDRAULIC FLUID CONSUMPTION

80" Hot Strip Mill

Rated Capacity	350 Tons/Hr.	2,620,000 Tons/Year
1975 Production	330 Tons/Hr.	1,980,800 Tons
Lubricant Consumption (1975)		3,400,800 Lbs.
Lbs. Lubricant/Ton Steel Rolled		1.72

45" Blooming or Slabbing Mill

Rated Capacity	220 Tons/Hr.	1,600,000 Tons/Year
1975 Production	195 Tons/Hr.	1,200,000 Tons

44" Blooming Or Slabbing Mill

Rated Capacity	200 Tons/Hr.	1,498,000 Tons/Year
1975 Production	165 Tons/Hr.	835,000 Tons/Year
1975 Total Production 44" & 45" Mills		2,035,000 Tons
Lubricant Consumption (1975)		3,914,820 Lbs.
Lbs. Lubricant/Ton Steel Rolled		1.9

Cold Strip Picklers

Rated Capacity	220/Hr.	1,647,360 Tons/Year
1975 Production		1,510,000 Tons
Lubricant Consumption (1975)		760,000 Lbs.
Lbs. Lubricant/Ton Steel Pickled		0.5

5 Stand Tandem Mill-Tin Plate

Rated Capacity	100 Tons/Hr.	748,800 Tons/Year
1975 Production		660,000 Tons
Lubricant Consumption (1975)		787,500 Lbs.
Lbs. Lubricant/Ton Steel Rolled		1.2

4 Stand Tandem Sheet Mill

Rated Capacity	90 Tons/Hr.	674,000 Tons/Year
1975 Production		576,000 Tons
Lubricant Consumption (1975)		686,400 Lbs.
Lbs. Lubricant/Ton Steel Rolled		1.19

Electrolytic Washers

Rated Capacity	100 Tons/Hr.	749,000 Tons/Year
1975 Production		638,000 Tons
Lubricant Consumption (1975)		6,525 Lbs.
Lbs. Lubricant/Ton Steel Washed		0.01

Table 8-20 (continued)

Electrolytic Tin Lines

Rated Capacity		261,360 Tons/Year
1975 Production		257,000 Tons
Lubricant Consumption (1975)		16,000 Lbs.
Lbs. Lubricant/Ton Steel Tinned		0.062

Blast Furnaces, Basic Oxygen Furnaces and Auxillaries

1975 Production		3,277,000 Tons
Lubricant Consumption (1975)		580,000 Lbs.
Lbs. Lubricant/Ton Hot Metal		0.18

Seamless Pipe Mill

Rated Capacity	56 Tons/Hr.	420,000 Tons/Year
1975 Production		315,500 Tons
Lubricant Consumption (1975)		178,000 Lbs.
Lbs. Lubricant/Ton Pipe		0.6

Buttweld Pipe Mills

Rated Capacity	45 Tons/Hr.	337,000 Tons Year
1975 Production		285,000 Tons
Lubricant Consumption (1975)		144,000 Lbs.
Lbs. Lubricant/Ton Pipe		0.51

(1.0 lb = 0.4536 kg and 1.0 ton = 907.2 kg)

Table 8-21. ROLLING OIL AND PROCESS OIL USAGE DATA

Rolling Oils

Tin Plate Mills Including Picklers - D A Mills*

Production	Pounds of Roll Oil Used	Lbs. Oil/Ton Steel
660,000 Tons	4,950,000 Lbs.	7.5 Lbs/Ton

Sheet Mills Including Picklers D A Mills

Production	Pounds of Roll Oil Used	Lbs. Oil/Ton Steel
576,000 Tons	1,750,000 Lbs.	3.04 Lbs/Ton

Threading Oils

Seamless Pipe Mills

Production	Pounds of Threading Oil Used	Lbs. Oil/Ton Pipe
315,000 Tons	540,000 Lbs	1.71 Lbs/Ton

Buttweld Pipe Mills

Production	Pounds of Threading Oil Used	Lbs. Oil/Ton Pipe
212,165 Tons	360,000 Lbs	1.71 Lbs/Ton

Coating Oils

Production	Pounds of Oil	Lbs. Oil/Ton Steel
274,000 Tons	328,800 Lbs	1.2 Lbs/Ton

*D.A. = Direct Application type lubrication system

(1.0 lb = 0.4536 kg)
(1.0 ton = 907.2 kg)
(1.0 lb/ton = 0.5 kg/1000 kg)

Table 8-22

Total Lubricant, Oil, Grease and Hydraulic Fluid Consumption

Department*		Consumption
80" Hot Strip Mill		3,400,800 lb
44" & 45" Blooming or Slabbing Mills		3,914,820 lb
Continuous Picklers		760,000 lb
Tin Plate Mills Including Picklers		787,500 lb
	Rolling Oil	4,950,000 lb
Sheet Mills Including Picklers		686,400 lb
	Rolling Oil	1,750,000 lb
Electrolytic Washers		6,525 lb
Electrolytic Tin Lines		16,000 lb
Blast Furnaces, BOF's, and Auxiliaries		580,000 lb
Seamless Pipe Mills		178,000 lb
	Threading Oil	540,000 lb
Buttweld Pipe Mills		182,000 lb
	Threading Oil	360,000 lb
Continuous Galvanizing Line		144,000 lb
	Coating Oil	328,800 lb
		18,584,845 lb

*Note: The steel production rate corresponding to these consumption data was 3,277,000 tons/yr.

(1.0 lb = 0.4536 kg)
(1.0 ton = 907.2 kg)

Appendix C also includes a lengthy listing of parts and equipment that are lubricated, the types of bearings or gears, the types of lubricants used, and monthly lubricant consumption rates. The approximate monthly consumption of lubricating oils and greases and hydraulic fluids are identified by their application. A summary tabulation of these detailed consumption estimates was prepared by PES and follows Lykins' input in the appendix. Subtotals of total lubricant, oil, grease and hydraulic fluid usage were calculated for the iron and steel making processes as well as for the steel shaping and finishing processes. Based on these calculations, it appears that approximately 90 percent of all the lubricants, oils, greases and hydraulic fluids consumed in an integrated steel mill are used in the shaping and finishing operations. Conversely, about 10 percent of these materials are used in the steel making and auxiliary processes.

In summary, Joseph Lykins provided PES primarily with consumption (usage) and application data. He was not responsible for providing detailed or comprehensive data on, or estimates of, lubricant fate. His data, in conjunction with that gathered by PES, are basically representative of an integrated steel mill although usage data varies greatly from one steel mill to another. A typical steel mill is also difficult to depict due to the variability in equipment design and maintenance, the type and size of mills, and the types of products produced. Finally, the usage data that was provided by the nine steel mills included in the study, were not sufficiently detailed, or in a format to be compared with the data from Mr. Lykins.

8.12 Lubricant Fate and Material Balance Information Supplied by Jablin

Richard Jablin was contracted by PES to provide technical assistance and information regarding the fate of steel mill lubricants and the material balance estimates. Based on his extensive experience in the steel industry and as a consulting engineer to EPA and industry sponsored studies of the steel industry, Jablin prepared a report for PES which is included as Appendix D. Background information relevant to the PES study were supplied as well as material balance data and estimates for an unidentified steel mill, labeled "Mill A." In addition, Jablin prepared a material balance estimate for a "typical" steel mill based on his experience and data, and the material balance data collected from the nine steel mills by PES. This "typical" steel mill material balance is presented and discussed in Section 9.

The total input of oils, greases and hydraulic fluids for Mill A, based on purchase records, are summarized in Table 8-23. A summary of the material balance estimate output terms is presented in Table 8-24. In making his analysis of Mill A, a small integrated steel mill, Jablin attempted to approach each loss term estimate from more than one viewpoint. For example, to estimate the quantity of oil on products the theoretical amount was calculated based on references to oil film thickness and the average gage of steel product rolled. A second method of estimating the quantity of oil on products leaving the plant was based on the quantity of coating oils applied minus the estimated amounts lost due to drippage and volatized during application. From the estimates of individual loss terms Jablin developed an overall "best" estimate taking into account all available data and including field observation and engineering judgment. The estimation method and logic regarding each loss term are summarized in the following pages of this section.

8.12.1 On-Product

Two approaches to estimating the amount of oil on-product were provided by Jablin. A graph relating the amount of coating oil on-product per quantity of cold rolled strip for an oil film thickness of 0.00025 cm (0.0001 inch) was utilized. The curve, included here

Table 8-23. MILL A OIL, GREASE AND HYDRAULIC FLUID PURCHASE DATA

Hydraulic Oils	284,000 gal/yr
Bulk Grease	253,000 lb/yr
Gear Oils	115,000 gal/yr
Coating Oils	58,000 gal/yr
Rolling Oils	31,000 gal/yr
Miscellaneous Greases	20,000 lb/yr
Miscellaneous Oils	7,000 gal/yr
Motor Oils	5,000 gal/yr
TOTAL*	534,125 gal/yr

*Note: Jablin converted grease data to gallons using a factor of 8 lb/gal. His material balance estimate for "Mill A" is in gallon units.

(1.0 lb = 0.4536 kg)
(1.0 gal = 3.785 l)

Table 8-24. SUMMARY OF MILL A MATERIAL BALANCE VALUES

Output Term	Quantity (gal/yr)	Percent of Input
Drained, collected	250,500	46.9%
In sludges	57,800	10.8%
Wastewater discharge	57,300	10.7%
Volatized	51,595	9.7%
On-Products	40,740	7.6%
On-Mill scale	36,800	6.9%
Trash and debris	19,825	3.7%
Leaks and spills	7,000	1.3%
Left in containers	1,382	.3%
TOTAL	519,342	97.9%
Input:		
TOTAL	534,125	
	Unaccounted for:	2.1%

(1.0 gal = 3.785 l)

as Figure 8-11, is independent of sheet width or coil size. From a breakdown of Mill A cold gages produced in 1976 it was calculated that the average gage was about 0.13 cm (0.050 inch). Jablin estimated the oil film thickness on Mill A cold rolled product to be 0.00064 cm (0.00025 inch). At 0.13 cm (0.050 inch) gage Figure 8-11 indicates a 0.50 l (0.12 gal) of coating oil per 1000 kg (ton) of product. Since an oil film thickness of 2.5 times that for which the curve was drawn was considered typical, Jablin concluded that the oil on-product loss term was 1.3 l (0.30 gal) of coating oil per 1000 kg (ton) of cold rolled sheet product. Approximately 1.2×10^8 kg (131,600 tons) of cold rolled product were made, resulting in a total oil on-product quantity of about 150,000 liters (39,500 gal) per year.

The second method of estimating the oil on-product loss term utilized the coating oil purchase data and estimates of the amounts of coating oil lost due to drippage and volatization. A total of 220,000 l/yr (58,000 gal/yr) of coating oils were applied. Of this amount, it was estimated that 22% was volatized when applied. The basis for this assumption concerning volatized coating oil is discussed in Subsection 8.12.5. An additional 19% of the remaining coating oil was estimated to be lost due to drippage from the product. The oil on-product calculation is as follows:

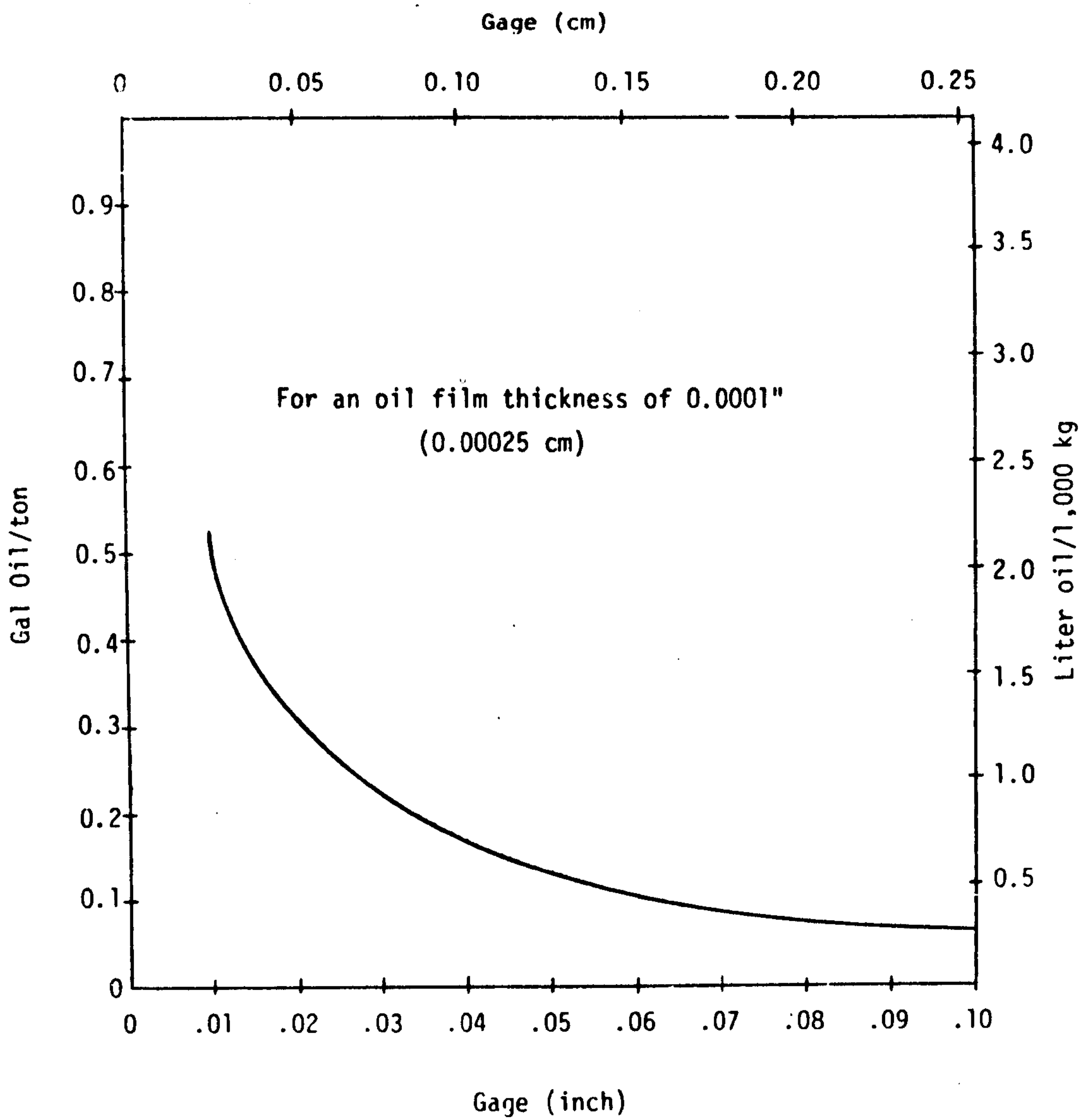
Total coating oil usage = 58,000 gal/yr (131,600 tons of product)
[220,000 l/yr]

Volatile loss = 22% x 58,000 gal/yr = 12,760 gal/yr [48,300 l/yr]

Drippage off product after application = 10% = 4,500 gal/yr
[17,000 l/yr]

Remaining on-product as shipped = 40,740 gal/yr (.31 gal/ton)
[154,200 l/yr]

The two methods of estimating oil on-product leaving the plant both yield a value of about 151,000 l/yr (40,000 gal/yr). For the Mill A



<u>Note:</u>

Steel Density = 502 lb/ft^3

Oil Density = 7.78 lb/gal

= 58.3 lb/ft^3

Independent of Sheet Width or Coil Size

Figure 8-11. Quantity of Coating Oil on Cold Rolled Strip as a Function of Gage material balance estimate Jablin used the 154,200 l/yr [40,740 gal/yr (.31 gal/ton)] value which accounts for about 7.6% of the total input.

8.12.2 On-Mill Scale

The range of oil content in mill scale from data reported by various steel mills is great. The bulk of the data obtained in the PES study and reported in the literature indicate a typical oil content of mill scale in the .2 to 1.0% range. At Mill A an average oil content of 0.4% by weight was cited by Jablin. From this value and mill scale quantity data a total of 139,000 l/yr (36,800 gal/yr) of oil on-mill scale was calculated and entered into the material balance estimate.

At Mill A mill scale is recycled to a sinter plant equipped with a scrubber for air pollution control. The scrubber reportedly captures about 8% [11,100 l/yr (2,940 gal/yr)] of the oil volatized from the mill scale. The remaining mill scale oil is volatized and discharged to the atmosphere via the sinter plant stack, or in part is combusted in the sinter machine.

8.12.3 Left in Containers and Lost in Storage

To estimate the amount of oils and greases left in containers or lost in storage Jablin applied the following logic. From field examination it was estimated that approximately 10% of the greases are left in the containers or drums. About 2% of the greases delivered and used in bulk system are lost in this manner. About 0.1% of the purchased oils are left in containers such as drums and bulk tanks. These quantities may be combusted with the drums if the drums are scrapped or cleaned by a drum reclaimer. To some extent oils and greases left in containers may drip to the ground and be cleaned up and disposed of with other solid wastes. The total quantity of oils and greases lost via this term is as follows:

oil:	.1% x	500,000 gal/yr =	500 gal/yr	[1890 l/yr]
drum grease.	10% x	2,500 gal/yr =	250 gal/yr	[950 l/yr]
bulk grease:	2% x	31,625 gal/yr =	632 gal/yr	[2390 l/yr]
		TOTAL	1,382 gal/yr	[5230 l/yr]

8.12.4 Leaks and Spills onto the Ground or Floors

This item will vary depending on oil handling facilities, operating practices and preventive maintenance procedures. From experience at Mill A, an average of about 3 major spills occur on the ground in a year with several more or less regular minor spills in addition. The total loss from these leaks and spills is estimated at 18,900 l/yr (5,000 gal/yr). In addition, an estimated 7,570 l/yr (2,000 gal/yr) results from drippage off coated product. This oil will eventually find its way into solid waste being cleaned up by slag for the most part. The total in this category is therefore 26,500 l/yr (7,000 gal/yr).

8.12.5 Volatized, Burned or Consumed

Laboratory tests were made by Jablin for the purposes of the project to determine the volatization loss of various types of oils, greases and hydraulic fluids. These laboratory test data are plotted in Figure 8-12 which was used to determine the percent weight loss of four types of oils and grease at the appropriate temperature. The four items tested represent 85% of the oils, greases and hydraulic fluids used in Mill A. They also represent the great bulk of the oils which are exposed to elevated temperatures. To translate these tests into an estimate of volatile loss requires estimating the "average" temperature to which the materials are exposed. These estimates are as follows:

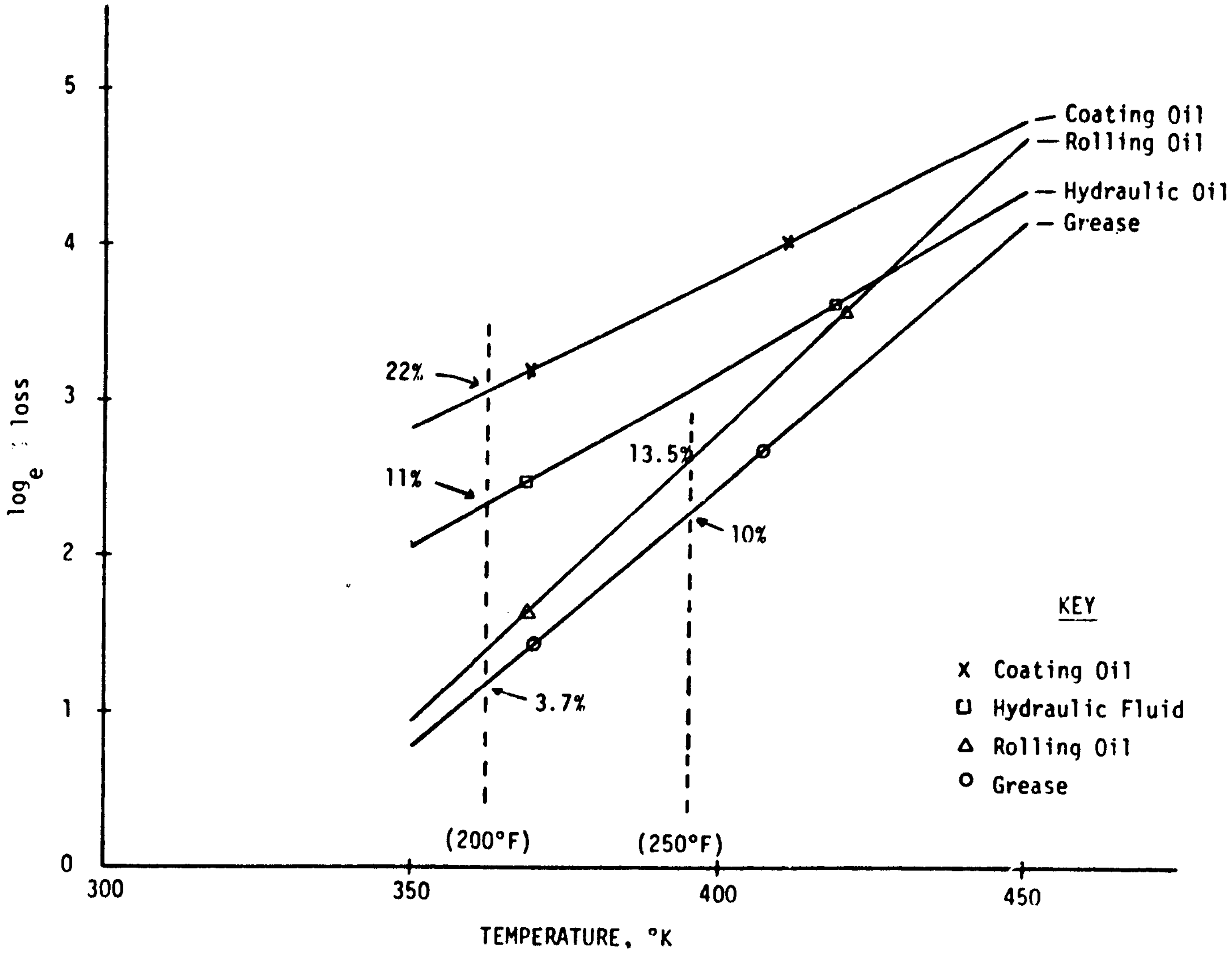


Figure 8-12. Percent Weight Loss After Exposure at Temperature for 30 Minutes

Grease	120°C	(250°F)	10%	loss
Coating Oil	95°C	(200°F)	22%	loss
Hydraulic Oil	95°C	(200°F)	11%	loss
Rolling Oil	120°C	(250°F)	13.5%	loss

Applying these percentage losses to the purchased quantities of oils, greases and hydraulic fluids for Mill A:

Grease 10% loss for 273,000 lb or (12,900 l/yr)	34,100 gal/yr =	3,410 gal/yr
Coating oil 22% loss for (48,300 l/yr)	58,000 gal/yr =	12,760 gal/yr
Hydraulic oil 11% loss for (118,000 l/yr)	284,000 gal/yr =	31,240 gal/yr
Rolling oil 13.5% loss for (15,800 l/yr)	31,000 gal/yr =	4,185 gal/yr
TOTAL VOLATILE LOSS		51,595 gal/yr (195,000 l/yr)

Obviously some items would be volatized to a greater degree because of exposure to high temperatures, such as table roll bearings, hot metal crane lubrication, etc. In other cases, the temperature would be less such as motor room bearings, hydraulic coil handling equipment, etc. The above is presented as a reasonable overall estimate.

8.12.6 In Sludges

Blast furnace and sinter plant scrubber wastewaters are treated by a clarifier before discharge. Oil concentration data for the wastewater entering and leaving the clarifier, along with the average wastewater flow rate, were used to calculate the quantity of oil in sludges resulting from iron and steelmaking operations. This calculation was performed as follows:

Oil into clarifier: 8 mg/liter

Oil out of clarifier: 1 mg/liter

Average wastewater flow rate: 9,840 lpm (2,600 gpm)

$$(8 \text{ mg/liter} - 1 \text{ mg/liter}) \left(9,840 \text{ lpm} \frac{60 \text{ min}}{\text{hr}} \frac{24 \text{ hr}}{\text{day}}\right) =$$

99 kg/day (218 lb/day) = 110 l/day (29 gal/day).

Based on 355 operating days per year the total quantity of oil on ironmaking sludges is approximately 39,000 l/yr (10,300 gal/yr).

Two methods of calculating the quantity of oil on sludges from the rolling operatins were employed by Jablin. The rolling mill wastewaters are treated by skimmers and a clarifier before being discharged. Concentrator sludge and clarifier underflow solids are generated at a rate of 3.25 kg/1000 kg (6.5 lb/ingot ton). At a production rate of 650 x 10^6 kg/yr (716,000 net ingot tons/yr), 208 x 10^6 kg/yr (2,290 tons/yr) of sludge and solids are generated. Analysis of concentrator sludge and clarifier underflow solids indicate that about 7% of the material by weight is carbon. Assuming that 90% of the oil is accounted for by carbon, and a 0.9 kg/l (7.5 lb/gal) oil density, a total of 180,000 l/yr (47,500 gal/yr) of oil are contained in the sludge from the rolling operations. An alternate method of calculating the oil content of rolling operation sludge was provided by Jablin. The clarifier underflow contains 2,096 mg/liter of oil and is withdrawn at a rate of 189 lpm (50 gpm). Multiplying these terms and converting to kg/day (lb/day) units yields a value of 570 (1,258). Based on 300 days/yr 0.9 kg/l and (7.5 lb/gal), a total of approximately 190,000 l/yr (50,300 gal/yr) are calculated (the typical operating rate of the clarifier).

Depending on the method used for calculating the oils in rolling operation sludge, a range from 219,000 to 229,000 l/yr (57,800 to 60,600 gal/yr) of oil in all plant sludges is obtained. A value of 219,000 l/yr (57,800 gal/yr) was selected by Jablin for use in the material balance estimate. This represents about 10.8% of the total oil, grease and hydraulic fluid input.

8.12.7 In Trash and Debris

Trash and debris were calculated to contain a total of 79,000 l/yr (20,825 gal/yr) of oil. This value was determined using the following estimates and assumptions:

Oil absorbent: 142,000 lb/yr @ 20% by weight oil = 3,800 gal/yr (14,400 l/yr);

Rags: 77,000 lb/yr @ 10% by weight oil = 1,025 gal/yr (3,900 l/yr)

Miscellaneous debris*: 3,000 tons/yr @ 2% by weight oil = 16,000 gal/yr (60,600 l/yr)

Total: 20,825 gal/yr (78,900 l/yr)

8.12.8 In Wastewater

NPDES discharge monitoring records were used to calculate the oil content of wastewaters from Mill A. The discharge from steel works average 5 mg/liter of oil and 11,400 lpm (3,000 gpm). Multiplying the oil concentration and flow rate data, converting units and summing the discharges, Jablin determined that approximately 217,000 l/yr (57,300 gal/yr) of oil was discharged in wastewaters, based on a 300 day/yr operating schedule for the wastewater treatment facilities.

8.12.9 Drained, Collected and Skimmed

The following data and estimates were provided concerning quantities of oil drained, collected and skimmed at Mill A:

Reclaimed oils by direct collection: 122,000 l/yr (32,150 gal/yr) (actual)

Reclaimed by cracking-water treatment: 583,000 l/yr (154,150 gal/yr) (actual)

Skimmed and retained on lagoon: 243,000 l/yr (64,200 gal/yr) (estimated)

TOTAL: 948,000 l/yr (250,500 gal/yr)

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*From floors, machine shops, degreasing, dirt, scrap metal, etc.

Reclaimed oil at Mill A is used exclusively for fuel. It is mixed with #6 fuel oil in the soaking pit oil tanks. Sludges from the reclaiming operation are estimated at 0.1%.

8.12.10 Comments on Material Balance Estimate for Mill A

As shown in Table 8-24, 97.9% of the oils, greases and hydraulic fluids purchased by Mill A are accounted for by the material balance loss terms. The 2.1% unaccounted for is not considered significant in light of the accuracy of the data and estimation methods. The unaccounted for 42,400 l/yr (11,200 gal/yr) is probably due to a slight error in all of the component figures and does not represent a major missing loss term. The weakest estimate, according to Jablin, is the loss via leaks or spills to the ground and general clean-up. Variations in reclaimed oil data, wastewater discharges and mill scale oil content values could also easily account for the 2.1%. Figure 8-13 illustrates the Mill A material balance estimate provided by Jablin.

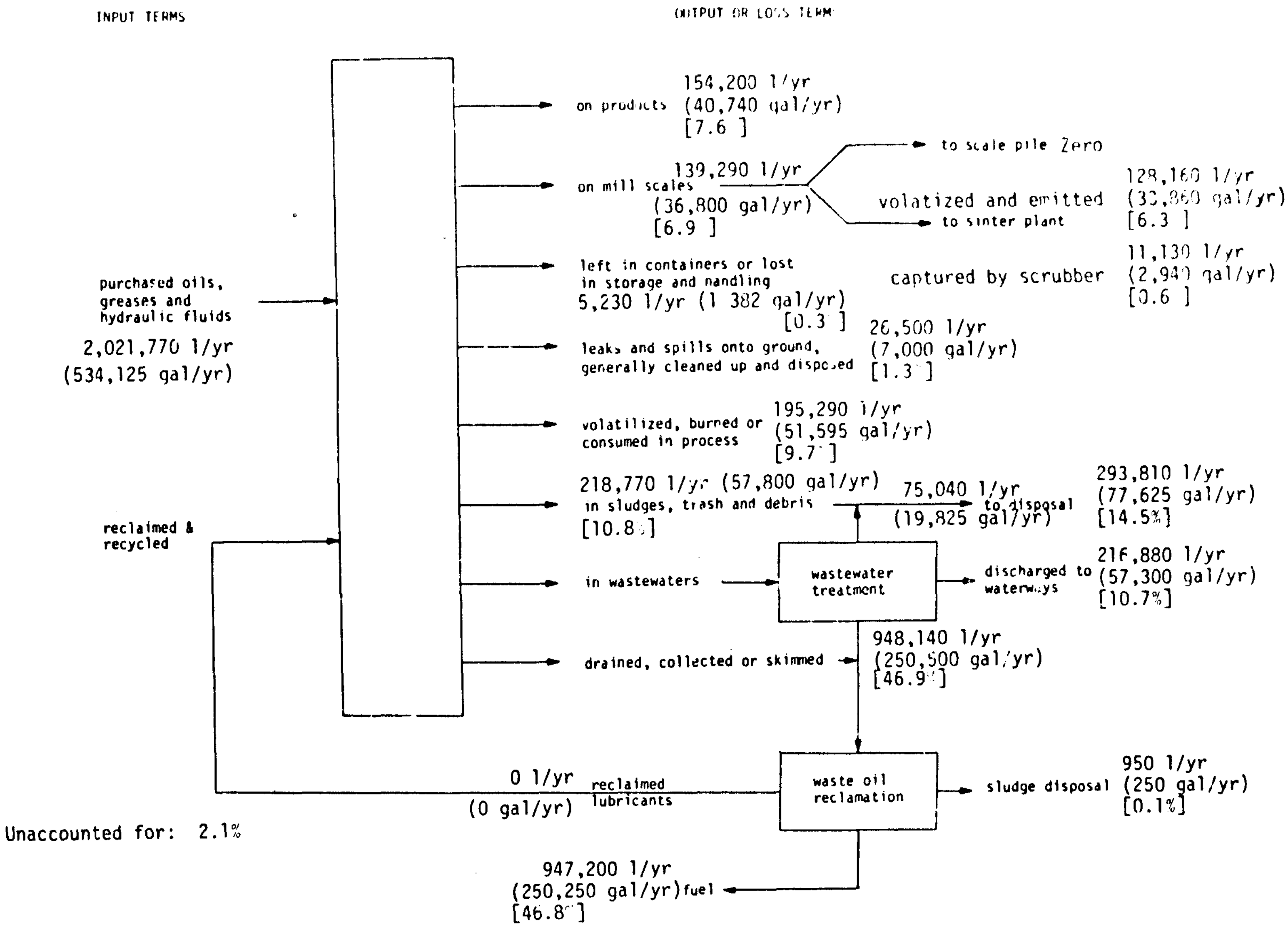

Figure 8-13. MATERIAL BALANCE - MILL A

9. DATA SUMMARY AND GENERALIZATIONS

A summary of the data obtained from the nine steel mills and the consultants is presented in this section along with generalizations concerning steel mill lubricant usage, material balance estimates and the fate of toxic substances. An effort has been made to present estimates for a typical integrated steel mill. Also, estimates are provided of total lubricant, oil, grease and hydraulic fluid usage by the steel industry in the United States and the resulting quantities of air and water pollution. A geographical breakdown of air and water pollution discharge estimates, resulting from the usage of lubricants, oil, greases and hydraulic fluids by steel mills, is included.

Only integrated steel mills were surveyed in the study. The applicability to non-integrated and specialty steel mills of the generalizations derived from the PES data base were not tested or investigated. Since 90% of the lubricants, oils, greases and hydraulic fluids used in the integrated steel plants is used in the shaping and rolling steps, one would expect similar usage rates for non-integrated or specialty steel plants engaged in these shaping and rolling operations. However, no data was obtained to substantiate this hypothesis. The differences in the types and sizes of equipment, as well as the types and quantities of products associated with non-integrated and specialty steel mills may significantly influence the quantity and types of lubricants and hydraulic fluids used. Differences in wastewater treatment facilities and waste oil recovery efforts, along with the factors influencing usage, could limit the similarities between non-integrated or specialty steel plants and integrated steel plants.

The integrated steel plant production capacity information contained in Table 1-1 (presented in Section 1) indicate that the average plant capacity is 2.9 x 10^9 kg/yr (3.2 x 10^6 tons/yr). The average production capacity of independent and specialty steel plants is roughly an order of magnitude smaller than for integrated steel plants. Independent and specialty steel plants account for only about 15 to 20% of the total raw steel production capacity in the United States.

The representativeness of the nine integrated steel mills surveyed by PES was also considered. The total raw steel production capacity of the nine surveyed mills is 41 x 10^9 kg/yr (45.2 x 10^6 tons/yr) or nearly 30% of the total capacity of all domestic integrated steel mills. The average raw steel production of the nine plants studied by PES is about 4.5 x 10^9 kg/yr (5 x 10^6 tons/yr) compared to 2.9 x 10^9 kg/yr (3.2 x 10^6 tons/yr) average for all integrated plants. A representative sampling of the types of shaping or rolling mills and steelmaking equipment was obtained by including nine different steel mills. The variety of products and differences in the relative quantities of these products at the nine steel mills are thought to be typical.

Estimates and generalizations have been made by PES for a "typical" steel mill. It must be pointed out that no two integrated steel mills are alike and describing in detail the equipment, lubricating practices and air or water pollution discharges at a "typical" steel mill would be difficult. Whenever data and circumstances permit, the lubricant usage and resulting air and water pollution discharges should be studied on a case by case basis. The generalizations and estimates made by PES are intended to be used as a starting point or basis from which to begin more detailed investigations. The generalizations and estimates for the "typical" mill and for the steel industry in general are intended to illustrate the magnitude and relative importance of the various items investigated.

9.1 Usage of Lubricants, Oils, Greases and Hydraulic Fluids

The usage data obtained from the nine mills and the consultants are summarized in this section. As mentioned in previous sections of the report, several factors influence the types and usage rates of lubricants, oil, greases and hydraulic fluids at an integrated steel mill. Two key parameters, steel production rate and the type of products made, have been considered by PES.

9.1.1 Usage Versus Steel Mill Production

A summary of monthly oil, grease and hydraulic fluid usage data are presented in Table 9-1. For each of the nine steel mills, the usage data, broken down by oils, greases and hydraulic fluids are tabulated along with the steel production capacity and number of rolling mills at each plant. Also included are usage data provided by Lykins. Pertinent remarks concerning the usage data appear in the last column.

The data in Table 9-1 along with the data concerning production rate and type of products made were analyzed in a variety of ways. Least squares correlations were made and correlation coefficients calculated for several combinations of the parameters in an effort to verify relationships between the usage of lubricants, oils, greases and hydraulic fluids and production capacity, production rate and finally type of product made. In all cases the inclusion of consultants' data had little influence on the calculated correlation coefficients indicating that the data provided by these consultants was consistent with the data obtained by PES directly from the steel industry. Since this was found to be the case, Lykins' usage data and Jablin's data for Mill A are included in the correlations.

The total monthly usage of all lubricants, oils, greases and hydraulic fluids was correlated to both the plant capacity and production rate. These parameters are tabulated in Table 9-2. Note that the

Table 9-1. MONTHLY OIL, GREASE AND HYDRAULIC FLUID USAGE DATA

STEEL MILL AND LOCATION	APPROXIMATE STEEL PRODUCTION CAPACITY[1] Kg/yr	Tons/Year	NUMBER OF MILLS[2]	OILS	GREASES	HYDRAULIC FLUIDS	REMARKS
United States Steel Corporation Gary, Indiana	7.3×10^9	(8.0×10^6)	31	567,750 l (150,000 gal.)	58,968 kg (130,000 lb.)	75,700 l (20,000 gal.)	No data for process or rolling oils.
South Chicago, Illinois	4.8×10^9	(5.25×10^6)	10	400,79 l (10,589 gal.)	116,422 kg (256,663 lb.)	82,600 l (21,823 gal.)	No data for process oils. No hot strip or cold rolling mills.
Inland Steel Company East Chicago, Indiana	7.4×10^9	(8.2×10^6)	30	1,126,038 l (297,500 gal.) (Oils and greases reported as one value)		157,710 l (41,667 gal.)	Rolling oils, lubricants and greases reported as one value.
Youngstown Sheet and Tube Company East Chicago, Indiana[3]	5.0×10^9	(5.5×10^6)	14	1,068,390 l (282,270 gal.)	99,978 kg (220,410 lb.)	438,380 l (115,820 gal.)	Value for "Oils" includes 40,360 gal of rolling and coating oils.
Bethlehem Steel Corporation Sparrows Point, Maryland	6.8×10^9	(7.5×10^6)	27	573,690 l (151,600 gal.)	149,234 kg (329,000 lb.)	243,750 l (64,400 gal.)	Value for "Oils" includes 55,000 gal of rolling oils.
Jones and Laughlin Steel Corporation Aliquippa, Pennsylvania	3.5×10^9	(3.84×10^6)	12	253,690 l (67,025 gal.)	140,699 kg (310,183 lb.)	91,154 l (24,083 gal.)	Value for "Oils" includes 10,000 gal of rolling oils.
Republic Steel Corporation South Chicago, Illinois	1.8×10^9	(2.0×10^6)	7	88,640 l (23,420 gal.)	25,687 kg (56,630 lb.)	56,510 l (14,930 gal.)	No hot strip or cold rolling mills.
Interlake, Inc. Riverdale, Illinois	0.8×10^9	(0.9×10^6)	16	127,365 l (33,650 gal.)	7,725 kg (17,030 lb.)	No Data	No data for process oils or hydraulic fluids.
Kaiser Steel Corporation Fontana, California	3.3×10^9	(3.6×10^6)	16	436,830 l (115,410 gal.)	55,661 kg (122,710 lb.)	56,850 l (15,020 gal.)	Satellite operations use 5 to 10% of these stocks
Estimate Provided by Lykins	2.7×10^9	(3.0×10^6)	--	439,440 l 116,100 gal.	55,755 kg 122,917 lb.	192,403 l (50,833 gal.)	

[1]The steel production capacity data was taken from the IISS Steel Industry in Brief. Most steel mills reported that production levels corresponding to the period for which lubricant usage data were reported were approximately 70% of capacity.

[2]The number of rolling mills listed represents the total primary and finish shaping and rolling mills as reported in the AISI Directory of Iron and Steel Works or by the steel mill during the PES survey.

[3]Youngstown Sheet and Tube reported usage rates per raw ton of steel produced. PES assumed that the plant was operated at 70% of the reported capacity listed in the IISS Steel Industry in Brief.

Table 9-2. TOTAL USAGE AND PRODUCTION DATA

Steel Mill	Total Oil, Grease & Hydraulic Fluid Usage		Production Capacity		Production Rate	
Units	kg/mo	(lb/mo)	10^9 kg/yr	(10^6 tons/yr)	10^9 kg/yr	(10^6 tons/yr)
USSC - Gary	637,310	(1,405,000)	7.3	(8.0)	4.6	(5.1)
USSC - South Chicago	226,688	(499,753)	4.8	(5.25)	3.3	(3.675)
Inland Steel	1,153,845	(2,543,750)	7.4	(8.2)	6.5	(7.2)
Youngstown Sheet & Tube	1,454,290	(3,206,100)	5.0	(5.5)	3.5	(3.85)
Bethlehem Steel	884,066	(1,949,000)	6.8	(7.5)	5.0	(5.5)
Jones & Laughlin	450,648	(993,493)	3.5	(3.84)	1.8	(2.0)
Republic Steel	156,152	(344,250)	1.8	(2.0)	1.4	(1.5)
Interlake	122,200	(269,400)	0.8	(0.9)	0.57	(0.63)
Kaiser Steel	499,384	(1,100,935)	3.3	(3.6)	2.3	(2.5)
Lykins Data	623,661	(1,374,915)	2.7	(3.0)	1.9	(2.1)

* Note: When actual production rates were unavailable a 70% production level was assumed.

usage data have been converted to mass units, using a 0.9 kg/l (7.5 lb/gal) factor, and all oils, greases and hydraulic fluids are included in the figures presented in the second column of the table. The raw steel production capacity of each mill is shown in the third column, while actual production rates are found in the last column. Plots of total usage versus production capacity and also production rate are provided in Figures 9-1 and 9-2. Also shown in each of these figures are the least squares line, correlation coefficient and regression equation. In both cases, statistically, there appears to be a strong correlation and the confidence limit on the correlation coefficient lies between 95 and 98%.

A few comments must be made regarding the data used to develop these correlations. As noted in the remarks column of Table 9-1, the usage data provided by some of the steel mills does not include process or rolling oils. In one case hydraulic fluid usage data were not available. Satellite operations at another mill used some of the lubricant stocks, resulting in a higher than actual usage value. The effect of these differences in the usage data is to add to the uncertainty or error inherent in the correlations.

Both production capacity and actual production rate were correlated to allow use of the PES findings with either type of data. For example the total quantity of oils, greases and hydraulic fluids used by the steel industry in 1975 have been estimated using AISI production rate data for that year. The total usage of oils, greases and hydraulic fluids was also calculated using IISS production capacity data. These calculations are provided on the next page.

According to these calculations, it is estimated that about 23 x 10^6 kg/month (50 x 10^6 lb/month) of oils, greases and hydraulic fluids are used by the domestic integrated steel mills. Stated another way, about 300 x 10^6 l/yr (80 x 10^6 gal/yr) of lubricants and hydraulic fluids are used by integrated steel mills.

CALCULATIONS OF TOTAL LUBRICANT USAGE

Usage vs Production Rate

$Y = 320{,}000X + 278{,}900$

For all 47 integrated steel mills and a total actual production in 1975 of 116.64? x 10^6 tons/yr (AISI):

$Y = 320{,}000 \quad X + 47 \cdot 278{,}900$

$= 37{,}325{,}440 + 13{,}108{,}300 = 50{,}433{,}740$ lb/month

or approximately 50 x 10^6 lb/month [23 x 10^6 kg/month]

Usage vs Production Capacity

$Y = 246{,}400X + 190{,}900$

For all 47 integrated steel mills and a total production capacity of 148.555 x 10^6 tons/yr:

$Y = 246{,}400 \quad X + 47 \cdot 190{,}900$

$= 36{,}603{,}950 + 8{,}972{,}300 = 45{,}576{,}250$ lb/month

or approximately 46 x 10^6 lb/month [21 x 10^6 kg/month]

Note: $Y = aX + b$ for $X_1, X_2, X_3 \ldots\ldots X_i \ldots\ldots X_n$

$$\sum_{i=1}^{n} Y = a \sum_{i=1}^{n} X + n \cdot b$$

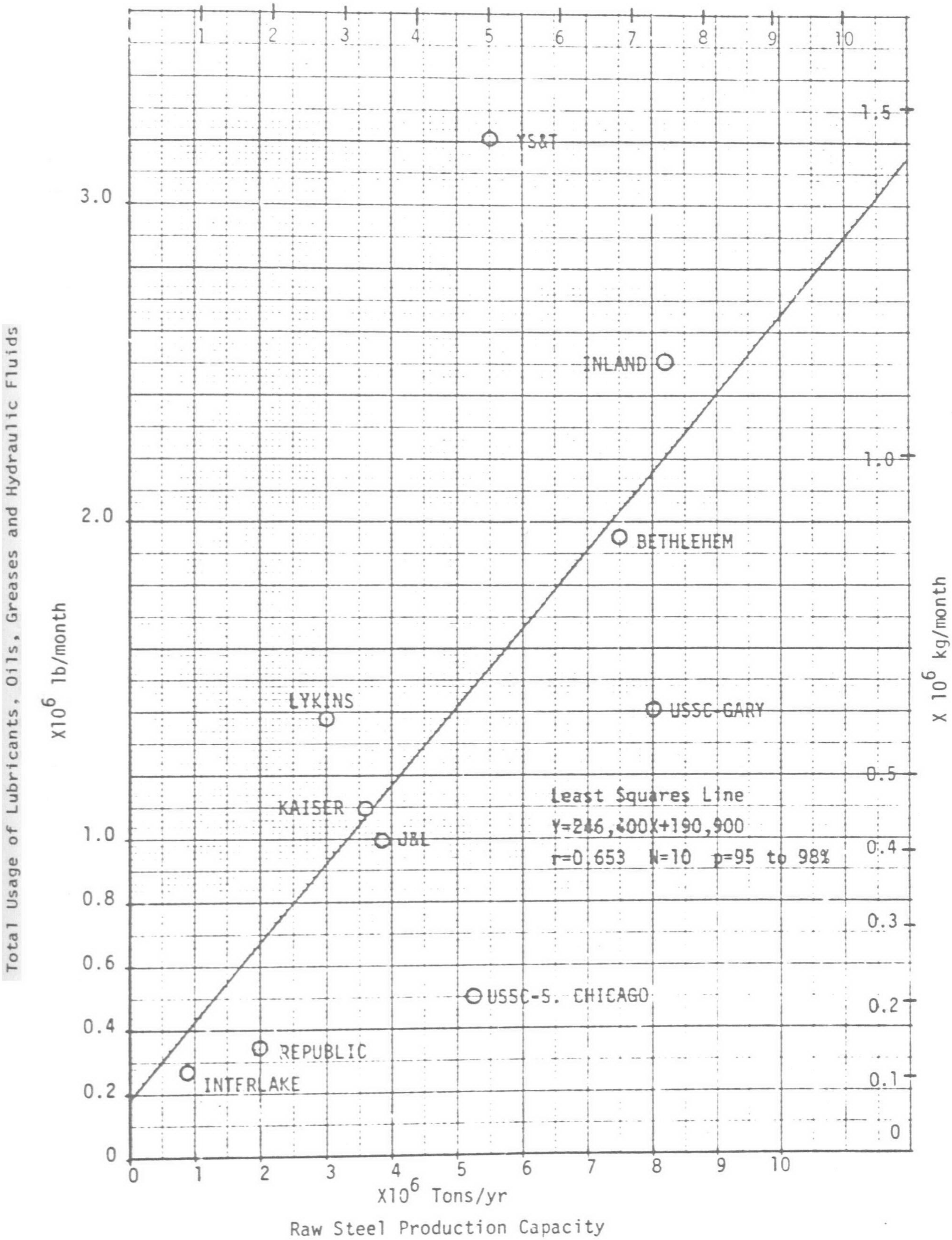

Figure 9-1. TOTAL USAGE VS. PRODUCTION CAPACITY

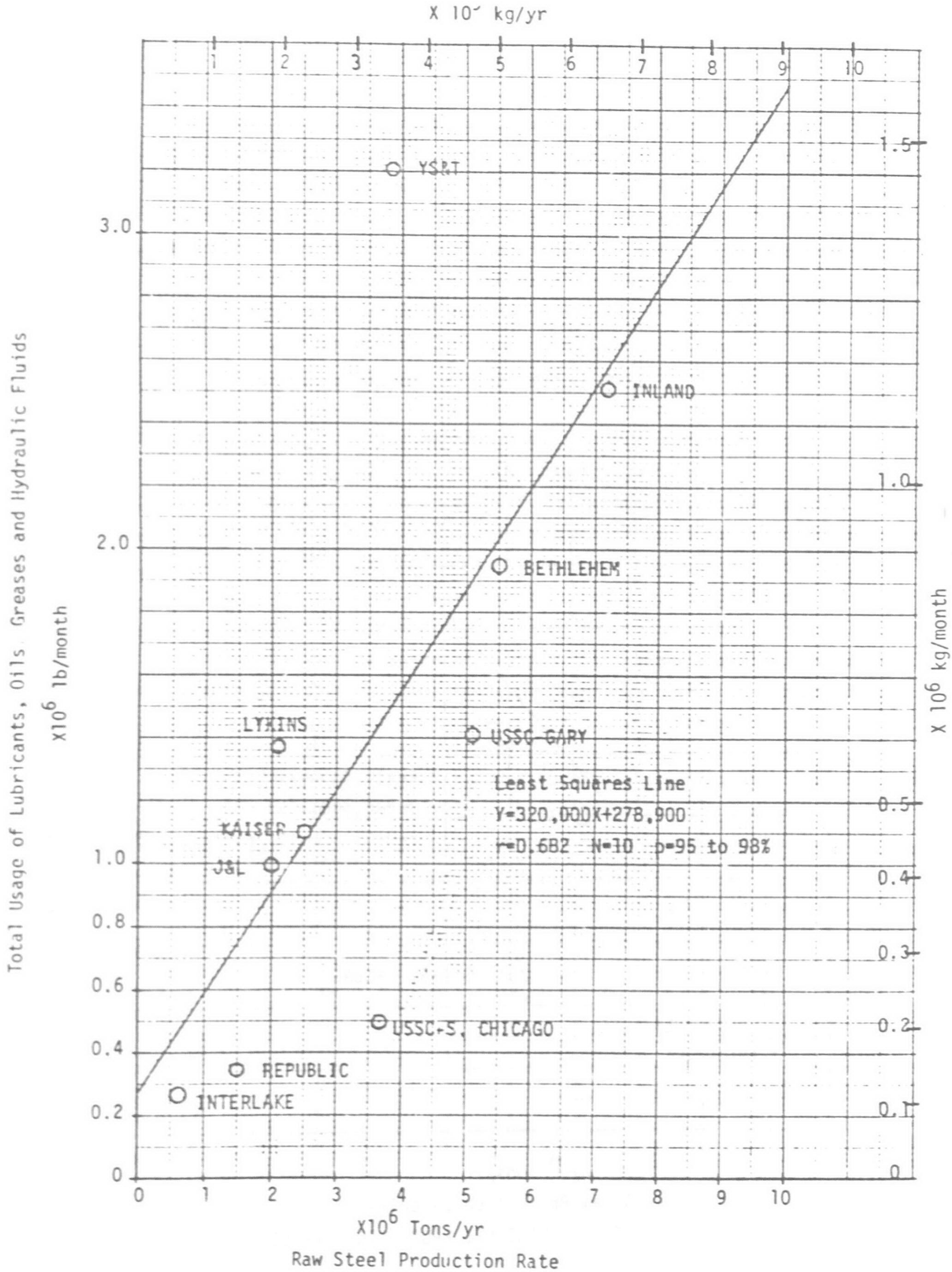

Figure 9-2. TOTAL USAGE VS. PRODUCTION RATE

The reader must be cautioned that estimating total oil, grease and hydraulic fluid usage using the PES correlations can provide only an order of magnitude value. As improved equipment lubrication, wastewater treatment and waste oil recovery practices are adopted by the steel mills (and such changes are taking place currently) the regression coefficients will change.

A second potential use for the calculated correlations would be for estimating the expected usage at a mill not studied by PES, using either production capacity or actual production rate data. Again major differences in equipment design and lubrication practice, as well as other factors influencing lubricant usage, could result in a much different actual usage value. New steel mills which can be expected to have much improved lubrication systems, wastewater treatment facilities and waste oil recovery efforts could be expected to differ significantly from the correlation. The use of the calculated correlations with either production capacity or actual production rate data would be appropriate if actual oil, grease, and hydraulic fluid data were not available. As will be demonstrated next, other factors besides production rate influence lubricant usage.

9.1.2 Usage Versus Product Type

An analysis of the correlation between lubricant usage and type of product made was performed. The total oil, grease and hydraulic fluid usage data for each of the nine steel mills were divided by the corresponding production rate data to obtain a kg/1000 kg (lb/ton) usage rate. Similarly the usage data for just oils (including lubricating, process and rolling oils) were converted to a 1/1000 kg (gal/ton) term. The kg/1000 kg and 1/1000 kg (lb/ton and gal/ton) usage rates are tabulated in the third and fourth columns of Table 9-3. The second column contains a parameter calculated by PES based on the rolling capacities of the various mills within

Table 9-3. USAGE AND PRODUCT DATA

Steel Mill	Product Parameter	Total Oil, Grease & Hydraulic Fluid Usage		Total Oil Usage	
USSC, Gary	59	1.653	(3.306)	1.473	(0.353)
USSC, South Chicago	0	0.816	(1.632)	0.146	(0.035)
Inland Steel	62	2.120	(4.240)	2.069	(0.496)
Youngstown Sheet & Tube	61	4.997	(9.993)	3.671	(0.880)
Bethlehem Steel	49	2.126	(4.252)	1.381	(0.331)
Jones & Laughlin	35	2.981	(5.961)	1.677	(0.402)
Republic Steel	0	1.377	(2.754)	0.780	(0.187)
Interlake	49	2.566	(5.131)	2.674	(0.641)
Kaiser Steel	39	2.642	(5.284)	2.311	(0.554)
Mill A	42	2.815	(5.630)	2.920	(0.700)
Units	%	kg/1000 kg	(lb/ton)	1/1000 kg	(gal/ton)

each steel mill. The AISI Directory of Iron and Steel Works for 1975 provided the source of rolling capacities. To obtain a relative percentage of rolled strip and coil products, the sum of all hot strip, cold rolling, cold finishing and temper mill capacities at each plant was divided by the sum of all shaping, rolling and finishing mill capacities. The parameter is expressed as a percentage. The calculation of the product parameter is included in Section 8, at the bottom of the equipment summary table provided for each of the nine steel mills. The two plants with no mills capable of producing strip or coil steel are assigned a product parameter of zero. The plants with large capacities to roll hot strip or cold rolled products have product parameters of around 60%. Sufficient input was provided by Jablin to include Mill A in this correlation.

The product parameter calculated using the capacity of mills may not agree precisely with the actual percentage of stip and coil products made at each still mill. It is at least an indicator of the products made at the various plants. Due to a lack of actual product data the product parameter was used to correlate lubricant usage.

Plots of the usage data versus product parameter are provided in Figures 9-3 and 9-4. Also shown on each of these figures are the least squares line, correlation coefficient and regression equation. The correlation between total oil, grease and hydraulic fluid usage per production rate and the product parameter has a correlation coefficient with a confidence limit of between 90 and 95%. The correlation between the usage rate of oil per production rate and the product parameter appears stronger. The confidence level for the correlation coefficient in this case is 98%. Again the reader is reminded that the remarks indicated in Table 9-1 concerning the usage data will affect the correlations. The lack of process or rolling oil data; and for one mill, hydraulic fluids, causes these usage terms to be lower than the actual case. On the other hand

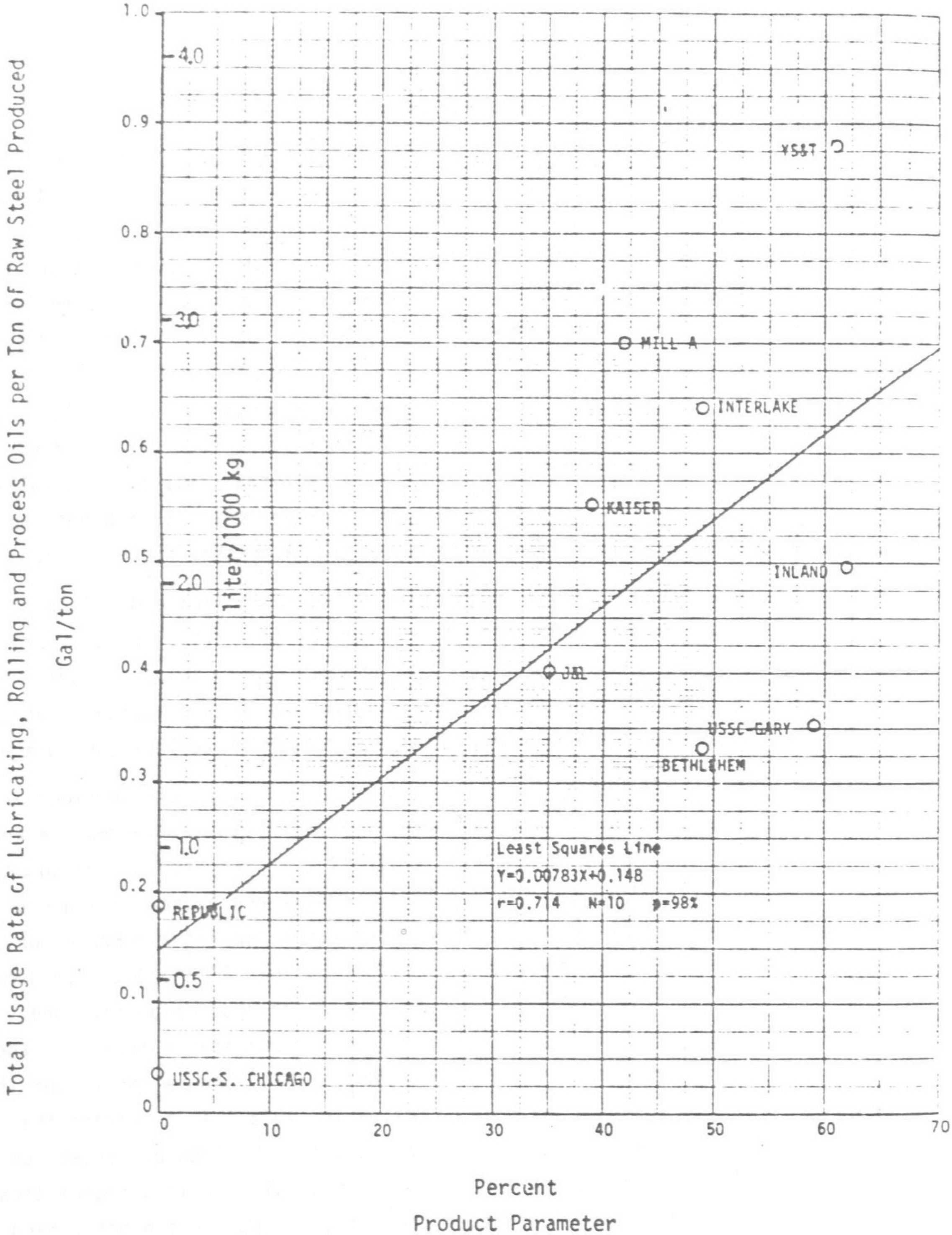

Figure 9-3. OIL USAGE RATE VS. PRODUCT PARAMETER

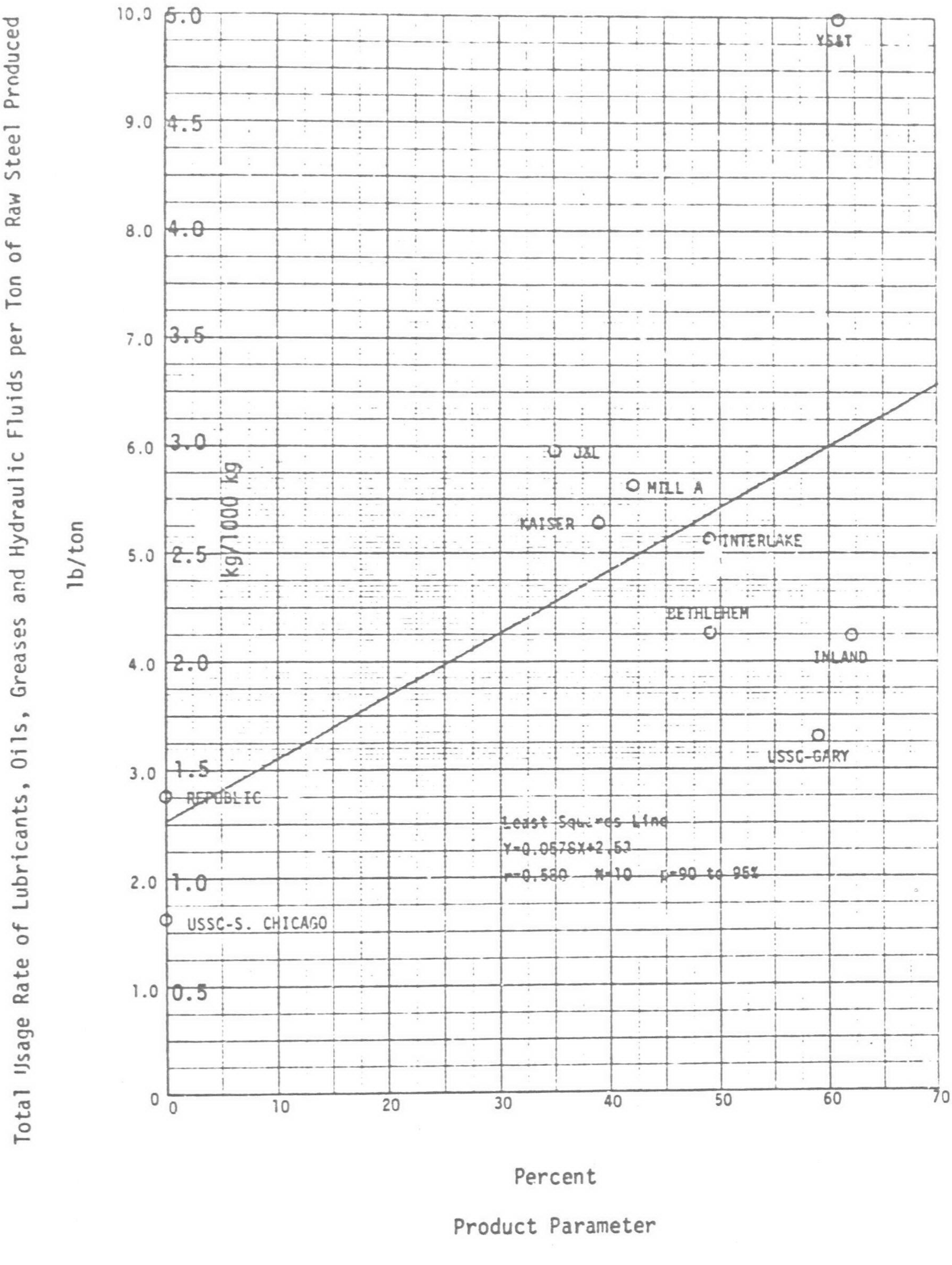

Figure 9-4. TOTAL USAGE RATE VS. PRODUCT PARAMETER

the use of a portion of Kaiser's lubricant stocks by a satellite operation results in a higher than actual usage rate. The oil usage rate for Inland Steel includes greases while the oil usage rate for Mill A includes hydraulic fluids. It is impossible to determine the magnitude of the error resulting from these discrepancies in the usage data. The regression equations are thought to be accurate for order of magnitude calculations.

9.1.3 Usage in Rolling Operations

Three steel mills surveyed provided lubricant and hydraulic fluid usage data by plant area, enabling an analysis of the relative amount used in the rolling operations. The hypothesis at the project outset was that the rolling operations were the major users of lubricants. On this assumption an effort was made to include in the study integrated steel mills which have relatively large numbers of rolling mills. A test of this hypothesis was called for.

The percentage of the total lubricants, oils, greases and hydraulic fluids used in the rolling operations at the three steel mills providing adequate data for such an analysis are listed below:

Bethlehem Steel	90%
Inland Steel	82%
Youngstown Sheet and Tube	98%

In addition to the percentages calculated by PES from steel mill usage data, Jablin reported that 90% of all lubricants, oils, greases and hydraulic fluids used at Mill A were associated with the rolling operations. These data for four integrated steel mills indicate that an average of about 90% of all lubricants, oils, greases and hydraulic fluids are used in the rolling operations. The ironmaking, steelmaking and auxiliary processes account for the remaining 10%. The other steel mills did not report usage data in a form that could be used to calculate the usage by the rolling operations.

9.1.4 Usage at a Typical Mill

The lubricant, oil, grease and hydraulic fluid usage data obtained from steel mills and the consultants have been summarized and correlated to different parameters in this section. As a final exercise usage calculations for a typical mill were performed. An integrated steel mill with annual production capacity of 3.6×10^9 kg/yr (4.0×10^6 tons) was selected. Integrated steel plant capacities range from about 0.8×10^9 to 7.4×10^9 kg/yr (0.9×10^6 to 8.2×10^6 tons/yr) and average around 2.9×10^9 kg/yr (3.2×10^6 tons/yr). A list containing integrated steel plants is provided in Section 1. A production capacity of 3.6×10^9 kg/yr (4×10^6 tons/yr) was considered to be typical by PES and the consultants.

Using the usage versus production capacity regression equation described in subsection 9.1.1 a total lubricant, oil, grease and hydraulic fluid usage rate per month was calculated to be 533,660 kg/month (1,176,500 lb/month) or roughly 0.54×10^6 kg/month (1.2×10^6 lb/month). Considering the accuracy of the correlation and due to variations in actual usage caused by the several factors influencing usage rates, this calculated value is thought to be a range of about $\pm 20\%$. No evaluation of error or uncertainty was possible due to the nature of the data.

If we assume that the typical steel mill is composed of various shaping, rolling and finishing mills such that a product parameter of 40% results, an oil usage rate (lubricating, process and rolling oils) of 1.9 l/1000 kg (0.46 gal/ton) of steel production is calculated using the appropriate PES correlation. Similarly a total lubricant, oil, grease and hydraulic fluid usage rate of 2.4 kg/1000 kg (4.8 lb/ton) of steel production is calculated. Applying the calculated 2.4 kg/1000 kg (4.8 lb/ton) usage rate to the 3.6×10^9 kg/yr (4.0×10^6 ton/yr) typical steel mill and assuming a 70% production level, a total usage of about 6.1×10^6 kg/yr or 0.5×10^6 kg/month (13.4×10^6 lb/yr or 1.1×10^6 lb/month) is obtained.

The regression equations determined from the steel mill data can be used to estimate approximate lubricant usage rates for integrated steel mills knowing the raw steel production capacity. The findings and regression equations presented in this section are, in effect, empirical relationships. The main intent of the study was not to develop a method of estimating steel mill lubricant usage per se, but such a procedure was needed to carry out the extrapolation of material balance loss term data to other integrated steel mills and the industry in general.

9.2 Material Balance Estimates

A summary of the material balance data and the generalizations regarding typical steel mill loss terms are presented in this section. Material balance estimates for eight integrated steel mills (seven mills surveyed by PES and Mill A) provided the basis for calculating average loss terms. Table 9-4 summarizes the loss term data, expressed as percentages of the total lubricant, oil, grease and hydraulic fluid input to each steel mill. From the available data the average value and range of values of each loss term were computed. The last column of Table 9-4 indicates the value selected as representative of a typical steel mill. In light of the wide range of values encountered and the recognized uncertainty in the data, whole number values were chosen for the typical mill.

9.2.1 Discussion of Loss Terms

The variability of the loss terms at different steel mills is thought to be caused by two factors. Errors or uncertainty in the data may result in a portion of the data spread; however, the principal cause of loss term variability can be attributed to differences in equipment and practices affecting the usage and fate of lubricants. In addition, the loss terms are interrelated at a given steel mill. The variability of data for each loss term is commented on in the following paragraphs.

Table 9-4. SUMMARY OF MATERIAL BALANCE LOSS TERMS

LOSS TERMS	USCC - GARY	INLAND	YS & T.	BETHLEHEM	J & L	REPUBLIC	KAISER	MILL A	AVERAGE	RANGE	"TYPICAL MILL"
On Products	3.6	3.4	1.5	4.7	19.4	5.0	0.9	7.6	5.8	0.9 - 19.4	6
On Mill Scales	1.1	13.7	3.6	2.3	20.1	9.3	34.3	6.9	11.4	1.1 - 34.3	11
Discharged to Waterways	7.1	3.7	11.7	14.1	9.8	7.0	0.1	10.7	8.0	0.1 - 14.1	8
In Sludge, Trash & Debris	28.5	21.8	46.8	55.6	52.8	54.7	35.0	14.5	38.7	14.5 - 55.6	39
To Reclaimers	53.8	14.1	12.1	14.5	0	0	8.5	46.9	18.7	0 - 53.8	19
Left in Containers	0.9	?	?	5.0	?	?	5.0	0.3	2.8	0.3 - 5.0	3
Leaks & Spills	0.7	0.4+ ?	0.2+ ?	3.7	?	?	5.0	1.3	1.9	0.2 - 5.0	2
Volatilized or Consumed	3.7	?	?	2.0	?	?	12.6	9.7	7.0	2.0 - 12.6	7
Total:	99.4	57.1	75.9	101.9	102.1	76.0	101.4	97.9			95
Unaccounted for:	0.6	42.9	24.1	-	-	24.0	-	2.1			5

Notes: 1. All numbers represent percentage of total lubricant, oil, grease and hydraulic fluid input to the steel mill.
2. Whole number values were selected for the "typical mill", reflecting the accuracy of available data and estimates.

Oil and grease in wastewater discharges account from about zero to fifteen percent of the total steel mill lubricant input. The wastewater treatment facilities and water use systems determine the amount of oil and grease discharged. For example, at Kaiser Steel where a nearly complete water recycle system is operated, the loss of oil to waterways is very low. In areas where water is more available and water use systems are not designed for recycle, the discharge of wastewaters containing oil is more significant. As improved wastewater treatment facilities and water recycle systems are installed, the percentage of oil discharged to waterways will decrease. Eventually zero discharge of wastewater may be required of all steel mills. The achievement of zero discharge is stated as a goal in PL 92-500, the Federal Water Pollution Control Act. Better wastewater treatment facilities, while decreasing the "discharged to waterways" loss term, will result in a higher "in sludge, trash and debris" loss term. Current practice typically calls for disposal of sludges and trash, along with the oil they contain, in a landfill. From the data it appears that about 15 to 55 percent of the oil, grease and hydraulic fluid purchased by steel mills are contained in sludge and trash in landfills. No data was obtained regarding the ultimate fate of oil in landfills.

Good wastewater treatment facilities are also related to waste oil recovery and reclamation practices. Current waste oil recovery and reclamation efforts vary widely in the steel industry. From zero to about half of the total oil, grease and hydraulic fluid input to steel mills is reportedly being collected and sent to reclaimers. The growing emphasis on waste oil recovery will increase the "to reclaimers" loss term while reducing the oil and grease wastewater discharge load. Recovered waste oils are mostly reclaimed as fuel oil and burned, although efforts to reclaim more valuable lubricants are increasing. The potential air pollution problems resulting from combustion of fuels reclaimed from steel mill waste oils was not evaluated during the project.

The three loss terms, "discharged to waterways;" "in sludge, trash and debris;" and "to reclaimers" are strongly interrelated for a given mill. Together they account for from 43.6 to [illegible].1 percent of the total lubricant input. On the average these three loss terms represent about 65 percent of the material balance.

The next most significant loss term is the quantity on mill scales. As indicated in Table 9-4 an average of about 11 percent of the oil, grease and hydraulic fluid input to a steel mill ends up on mill scales. The fate of oil on mill scales is determined by the method of handling the scales. Mill scales are either stockpiled or recycled to a sinter plant or the melt shop. Oil on stockpiled mill scale is thought to remain attached to the metal fines, although it is expected that some of the oil may partially be washed off by storm run-off. No data or information could be obtained regarding the fate of oil in scale piles. The oil in recycled mill scale is volatized or combusted depending on flame temperatures. It is thought that the oil on mill scale returned directly to the melt shop is combusted while oil on scale sent to the sinter plant is volatized. The type of air pollution control equipment installed on the sinter plant affects the ability of the sinter plant to handle mill scale with attached oil and also the amount of hydrocarbons emitted to the atmosphere. The fate of oil on mill scales for the eight steel mills is shown in Table 9-5. Of the total steel mill lubricant input about 11 percent is attached to mill scales. By fate, six percent goes to the scale pile and 5 percent is contained on recycled mill scale. Future recovery of oily mill scale is under study by the steel industry. When a technically and economically feasible method of removing the attached oil is developed, the fate of oil on mill scale will change. Much less mill scale (and attached oil) will be stockpiled and possibly more oil will be recovered. Changes in sinter plant air pollution control equipment will also affect the quantity of hydrocarbons emitted and captured at the sinter plant.

Table 9-5. FATE OF OIL ON MILL SCALES

Steel Mill	Total	To Scale Pile	To Sinter Plant/Melt Shop	
USSC - Gary	1.1	0	1.1	emitted
Inland	13.7	13.6	0.1	emitted
YS & T	3.6	2.2	1.4	emitted or burned
Bethlehem	2.3	0	2.3	1.7 emitted 0.6 captured
J & L	20.1	0	20.1	emitted
Republic	9.3	0	9.3	combusted
Kaiser	34.3	34.3	0	-
Mill A	6.9	0	6.9	6.3 emitted 0.6 captured
Average	11.4	6.3	5.1	

Note: All numbers represent the percentage of the total lubricant, oil, grease and hydraulic fluid input to the steel mill.

The amount of oil volatized or consumed in process or use at steel mills account for an average of seven percent. This term varied from 2 to 12.6 percent for the eight mills investigated. Two opportunities are provided for volatizing oil, grease and hydraulic fluid. The use of oil and grease in equipment or application on product at high temperature (above 66°C [150°F]) results in some loss. A second opportunity for volatizing oil occurs when water containing oil is used to cool or quench metal, slag or equipment. As mentioned previously, the required shift to complete wastewater recycle at steel mills will result in greater quantities of volatized oil. At Kaiser where nearly complete water recycling is practiced, the volatized loss term is 12.6 percent.

Oil on products accounts for a six percent loss term. This fate or loss term is affected primarily by the type of product made and is essential since rust prevention or protection is required for some types of product.

The amount of oil, grease and hydraulic fluid left in containers or lost in storage and handling represents about three percent of the lubricant input. It is thought that little can be done to alter this, although the increasing cost of lubricants will stimulate more efficient handling. The fate of oil, grease and hydraulic fluid left in containers is not known specifically for each mill.

Leaks and spills which are generally cleaned up and disposed of account for an estimated two percent of the total input. This will vary with equipment age and maintenance. As lubricant costs increase and requirements for better leak and spill prevention efforts are adopted by the operating and maintenance personnel, this loss term may decrease.

9.2.2 Typical Steel Mill Material Balance

The loss term percentages for a typical steel mill, shown in the last column of Table 9-4, were applied to the total oil, grease and hydraulic fluid usage rate estimated previously for a 3.6×10^9 kg/yr (4×10^6 ton/yr) capacity plant. As computed in section 9.1.4, this total usage rate is about 544,000 kg/month (1,200,000 lb/month). Multiplying this usage rate by the loss term percentages, a material balance estimate was derived for a typical mill. Figure 9-5 illustrates the calculated material balance. The fate of oils sent to reclaimers (21%) was assumed to be distributed as follows:

fuel	15%
reclaimed lubricant	5%
sludge from the reclamation process	1%

9.3 Air and Water Pollution Discharges and Solid Wastes

Using the typical lubricant usage rate and loss term percentages determined during the study, estimates were made of the quantities of air and water pollution discharges and solid wastes resulting from the use of oils, greases and hydraulic fluids in the steel industry. These estimates for a typical steel mill, and the entire domestic steel industry, are described in this section. The assumptions and logic used to develop the air, water and solid waste pollution loads or contributions are identified, also. The pollution estimates were computed to determine the magnitude and relative importance of potential environmental problems stemming from the use of lubricants by the steel industry.

9.3.1 Estimation Procedure

The first step in preparing estimates of the quantities of air and water pollution and solid wastes was to relate the loss terms to the air, water and solid waste pollution categories. For each loss term, the contribution (as a percentage of the total steel mill lubricant input) to either air pollution, water pollution or solid waste was assumed. Table 9-6 summarizes the results of this process. The decision or assignment of the loss term percentage to a type of

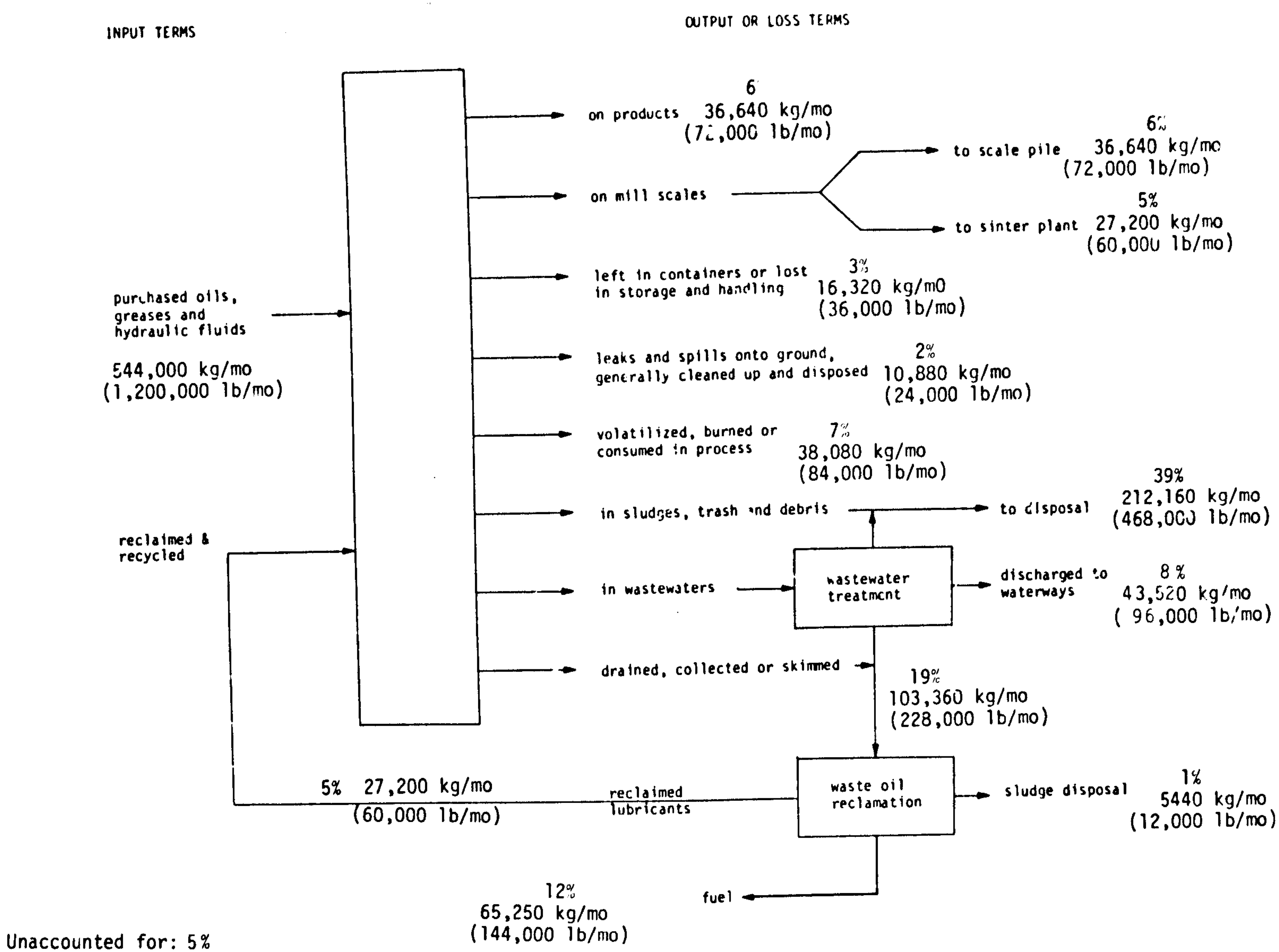

Figure 9-5. TYPICAL STEEL MILL MATERIAL BALANCE

Table 9-6. POLLUTION SUMMARY

Loss Term	Percent	Air Pollution	Water Pollution	Solid Waste	Assumptions
On Products	6	-	-	-	No resulting pollution.
On Mill Scales	11 → 6	-	1	1	Of the 6% of oil in stockoiled mill scale 1% is washed off and becomes water pollution and 1% is permanently "stored."
	→ 5	4	-	-	Of the 5% of oil in recycled mill scale 4% is volatilized and the remainder is combusted or captured.
Discharged to Waterways	8	-	8	-	
In Sludge, Trash & Debris	39	-	-	39	The fate of oil in landfills was not considered.
To Reclaimers	19	-	-	1	One percent sl dge from the reclamation process. The potential air pollution from fuel combustion was not considered.
Left in Containers	3	-	-	1	One percent is in containers which are discarded in a landfill.
Leaks & Spills	2	-	-	2	All leaks and spills are cleaned up and disposed of in landfills.
Volatilized or Consumed	7	6	-	-	One percent is combusted.
Total	95	10	9	44	32% does not result in air or water pollution or solid waste and 5% is unaccounted for.

pollution was straightforward in some cases. For example the oil and grease discharged to waterways is obviously a source of water pollution. In other cases, such as oil and grease left in containers or lost in handling or storage, assumptions had to be made with little information upon which to base them. The goal was to identify the potential pollution sources and the relative magnitude for a typical steel mill. The assumptions made by PES are noted in the last column of Table 9-6.

A total of 10 percent of the oils, greases and hydraulic fluids result in air pollution, 9 percent contribute to water pollution, and 44 percent become solid waste. The remaining 32 percent does not result in a pollution or solid waste problem. Five percent is unaccounted for. The nature of the loss term data and the number of assumptions needed to arrive at these pollution percentages limit the confidence that can be placed on their accuracy or correctness. It is thought that realistically a range of values should be stated. The percentage of the total oil, grease and hydraulic fluid input to a typical integrated steel mill which enters the environment can be summarized as follows:

Air pollution	5 to 15 %
Water pollution	5 to 15 %
Solid waste	30 to 60 %

9.3.2 Pollution Estimates

The pollution percentages were applied to the lubricant usage rate for a typical integrated steel plant [3.6 x 10^9 kg/yr (4 x 10^6 tons/yr)] raw steel production during 1975. At a typical steel mill, 544,000 kg/month (1,200,000 lb/month) of oil, grease and hydraulic fluid is used resulting in roughly 54,400 kg/month (120,000 lb/month) of air pollution, 43,520 kg/month (96,000 lb/month) of water pollution and 239,500 kg/month (528,000 lb/month) of solid waste. These calculations are shown on the next page.

Pollution Estimate for a Typical Integrated Steel Mill
[3.6×10^9 kg/yr (4×10^6 tons/yr) raw steel production capacity]

Total oil, grease and hydraulic fluid input = 544,000 kg/mo (1,200,000 lb/mo)

<u>Air Pollution</u>:

10% x 544,000 kg/mo (1,200,000 lb/mo) = 54,000 kg/mo (120,000 lb/mo)

5 to 15% = 27,200 to 81,600 kg/mo (60,000 to 180,000 lb/mo)

<u>Water Pollution</u>:

9% x 544,000 kg/mo (1,200,000 lb/mo) = 43,520 kg/mo (96,000 lb/mo)

5 to 15% = 27,200 to 81,600 kg/mo (60,000 to 180,000 lb/mo)

<u>Solid Waste</u>:

44% x 544,000 kg/mo (1,200,000 lb/mo) = 348,160 kg/mo (528,000 lb/mo)

30 to 60% = 163,200 to 326,400 kg/mo (360,000 to 720,000 lb/mo)

The total usage of oil, grease and hydraulic fluid by integrated steel mills was estimated to be about 23 x 10^6 kg/month or 300 x 10^6 l/yr (50 x 10^6 lb/month or 80 x 10^6 gal/yr) (see p. 9-6). Multiplying this usage rate by the pollution percentages it is estimated that 2.3 x 10^6 kg/mo (5 x 10^6 lb/mo) of air pollution, 2.1 x 10^6 kg/mo (4.5x 10^6 lb/mo) of water pollution and 10 x 10^6 kg/mo (22 x 10^6 lb/mo) of solid waste is generated.

As a final exercise, the geographical distribution of the air and water pollution discharges and solid waste was computed using raw steel production data tabulated by states in the AISI Annual Statistical Report 1975. These estimates are summarized in Table 9-7.

9.4 Fate of Toxic Substances

As discussed in Chapter 3 of this report, most of the materials used as lubricants and hydraulic fluids are derived from petroleum by various refining processes. These base oils are identical to those used in the automotive industry and almost all other lubricants, except for extremely high performance applications. Base oils are generally considered to be non-toxic to humans because they have been used extensively in the automotive service industry without adverse effects. They do have adverse effects on marine life and water fowl, and water pollution discharges are monitored to see that allowable limits are not exceeded. At high temperatures or during combustion, toxic polynuclear organic compounds may be formed from base oils. The sinter plant is an obvious location where this might occur. It is impossible to estimate the magnitude of these emissions without actual test data, but they will be found as a trace compound of the suspended particulate matter coming from the sinter plant.

Table 9-7. GEOGRAPHICAL DISTRIBUTION OF POLLUTION

States	EPA Region	1975 Raw Steel Production	Percent of Total Steel Production	Air Pollution	Water Pollution	Solid Waste
Pennsylvania	III	23.370 (25.761)	22.1	501,228 (1,105,000)	451,098 (994,500)	2,205,403 (4,862,000)
Indiana	V	17.969 (19.807)	17.0	385,560 (850,000)	347,000 (765,000)	1,696,464 (3,740,000)
Ohio	V	17.799 (19.620)	16.8	381,024 (840,000)	342,916 (756,000)	1,676,506 (3,696,000)
Illinois	V	8.666 (9.552)	8.2	185,976 (410,000)	167,376 (369,000)	818,294 (1,804,000)
Michigan	V	8.249 (9.093)	7.8	176,904 (390,000)	159,210 (351,000)	778,378 (1,716,000)
New York	II	3,085 (3.401)	2.9	65,772 (145,000)	59,194 (130,500)	289,397 (638,000)
California	IX	3,040 (3.351)	2.9	65,772 (145,000)	59,195 (130,500)	289,397 (638,000)
Kentucky	IV	1.888 (2.081)	1.8	40,824 (90,000)	36,740 (81,000)	179,626 (396,000
Minnesota, Missouri, Oklahoma, Texas, Nebraska, Iowa	V, VI, VII	4.898 (5.399)	4.6	104,328 (230,000)	93,894 (207,000)	459,043 (1,012,000)
Rhode Island, Connecticut, New Jersey Delaware, Maryland	I, II, III	4.621 (5.094)	4.4	99,792 (220,000)	89,811 (198,000)	439,085 (968,000)
Virginia, West Virginia, Georgia, Florida North Carolina, South Carolina, Louisiana	III, IV, VI	4.350 (4.795)	4.1	92,988 (205,000)	83,688 (184,500)	409,147 (902,000)
Arizona, Colorado, Utah Washington, Oregon, Hawaii	VIII, IX, X	3.974 (4.380)	3.8	86,184 (190,000)	77,564 (171,000)	379,210 (836,000)
Alabama, Tennessee, Mississippi, Arkansas	IV, VI	3.908 (4.308)	3.7	83,916 (185,000)	75,523 (166,500)	369,230 (814,000)
		105.818 x 10^9 kg/yr (116.642) x10^6 ton/yr	100 %	2,268,000 kg/mo (5,000,000) lb/mo	2,041,200 kg/mo (4,500,000) lb/mo	9,979,200 kg/mo (22,000,000) lb/mo

The rest of this discussion deals with the fate of toxic compounds that are present in the original lubricants and pass through the chain of use without undergoing any profound chemical transformations. Lubricant additives and fire-resistant hydraulic fluids are the main substances under consideration here. Additives are used to impart specific lubrication properties for particular applications and, as a result, are not found distributed uniformly throughout the steel mill. It is of interest, therefore, to attempt to determine whether these additives find their way to the scale pits, solid waste disposal, wastewater or other of the final destinations of steel mill lubricants, and to estimate the quantity of each additive that is involved.

9.4.1 Sulfurized and Phosphorized Fatty Oils

Sulfurized and phosphorized fatty oils are used as EP additives in gear oils and greases in quantities equivalent to .024 - .03% phosphorus and .7 - .9% sulfur. These EP lubricants are used primarily in hot and cold forming operations, and to a lesser extent in iron and steel production. Sufficient information was supplied by Kaiser and Republic, and by a consultant (Lykins) to permit rough estimations of the quantities of additives used in the mills and their ultimate fates. Table 9-8 shows these estimates.

The total yearly usage of these additives is small -- less than 295 kg (650 lb) (as P) of phosphorized fatty oils and less than 8,795 kg (19,390 lb)(as S) of sulfurized fatty oils for the mills listed. The bulk of the material probably is found in sludges and other solid waste, a lesser amount on mill scale, and still smaller amounts in wastewater and in volatiles from the scale pile. Since the toxicity of these substances has not been reported, it is not possible to estimate the risks associated with their handling and disposal.

Table 9-8. USAGE OF SULFURIZED AND PHOSPHORIZED OILS AS EP ADDITIVES

	Kaiser	Republic	Lykins
Iron and Steel Production			
EP lubricant usage	0.009 kg/1000 kg (.018 lb/ton)	very little	0.055 kg/1000 kg (.109 lb/ton)
Total yearly EP additive use (as S)	149 kg (328 lb)	very little	653 kg (1,440 lb)
Total yearly EP additive use (as P)	5 kg (11 lb)	very little	22 kg (48 lb)
Probable fate	solid waste or volatilized	solid waste or volatilized	solid waste or volatilized
Hot Forming			
EP lubricant usage	.342 kg/1000 kg (.683 lb/ton)	.281 kg/1000 kg (.562 lb/ton)	.313 kg/1000 kg (.626 lb/ton)
Total yearly EP additive use (as S)	5,625 kg (12,400 lb)	2,753 kg (6,070 lb)	6,124 kg (13,500 lb)
Total yearly EP additive use (as P)	187 kg (413 lb)	92 kg (202 lb)	205 kg (451 lb)
Probable fate	mill scale and sludge	mill scale, sludge and waste water	mill scale, sludge and waste water
Cold Rolling			
EP lubricant usage	.160 kg/1000 kg (.319 lb/ton)	no cold rolling	.103 kg/1000 kg (.206 lb/ton)
Total yearly EP additive use (as S)	2,626 kg (5,790 lb)	no cold rolling	2,018 kg (4,450 lb)
Total yearly EP additive use (as P)	88 kg (193 lb)	no cold rolling	67 kg (148 lb)
Probable fate	solid waste	no cold rolling	sludge, solid waste
Other			
EP lubricant usage	-0-	.031 kg/1000 kg (.062 lb/ton)	.124 kg/1000 kg (.248 lb/ton)

9.4.2 Zinc Dialkyl Dithiophosphate

Zinc dialkyl dithiophosphate is used in many lubricants and hydraulic fluids, and, as a result, is found throughout the steel mill. Total quantities used of this additive are given below:

	Kaiser	Republic	Lykins
Quantity of lubricant per ton of steel produced	0.938 kg (2.068 lb)	0.621 kg (1.369 lb)	0.460 kg (1.015 lb)
Total yearly use of zinc dithiophosphate	18,100 kg (40,000 lb)	7,080 kg (15,600 lb)	10,500 kg (23,100 lb)
Probable fate	all locations	all locations	all locations

This additive is used in larger quantities than the EP additives discussed in Section 9.4.1, but they are still relatively small amounts. Most of the U.S. production of zinc dialkyl dithiophosphate is used in motor oils, so any hazards associated with its use in the steel industry would be encountered to a much greater extent in the automotive service industry.

9.4.3 Phosphate Ester Hydraulic Fluids

Phosphate ester hydraulic fluids are used by some steel mills in applications that require fire resistant fluids. These materials are more expensive than other fire resistant hydraulic fluids, so there is an incentive to use cheaper substitutes whenever possible. Kaiser reported no use of phosphate ester fluids, but Republic indicated purchase of 625 liters (165 gallons) of some hydraulic fluid that was categorized as "other" and which we have assumed to be a phosphate ester type since all other categories were identified. In the list of lubricants recommended by Lykins for an integrated steel mill, 4,540 kg/yr (10,000 lb/yr) of phosphate ester hydraulic fluid was suggested. These fluids are used in hydraulic systems for coke ovens, furnaces and hot forming mills. Spills account for most losses of hydraulic fluids, and material from these spills probably is cleaned up and combined with other trash which goes to solid waste disposal. At the present time it is not known whether these materials are leached by rain and eventually find their way into the waterways.

9.4.4 Other Lubricant Additives

Other lubricant additives are assumed to be non-toxic as explained in Section 3.3 and have been omitted from this discussion. Lead naphthenate is a toxic additive, but it has not been included in the discussion because it is being phased out of use and soon will not be used at all.

10. RECOMMENDATIONS FOR ADDITIONAL STUDY

During the course of the project several areas were identified as potential topics for additional study. This section provides a brief outline or description of potential study topics for use by EPA.

10.1 Oil in Landfilled Sludge and Trash

It was determined that a large percentage of the oil, grease and hydraulic fluid used by the steel industry is contained in sludges, trash and debris which are generally disposed of in landfills. The ultimate fate of this oil and grease and the potential environmental problems associated with oily materials in landfills are unknown. It is suspected that storm or rain water will carry off at least a portion of the oil contained in landfills. Estimates for the entire steel industry indicate about 10×10^6 kg/month (22×10^6 lb/month or 132,000 tons/yr) of oil and grease are placed in landfills. An effort to verify this estimate, as well as to determine ways of reducing the quantity of oils landfilled, could be performed for the steel industry. The feasibility of recovering some oils or recycling certain oily sludges should be included in the study.

The first project step would be to verify and possibly improve the accuracy of the quantity of oil in landfilled sludge and trash. A literature search is called for, but it is expected that industry contact will be required to obtain the necessary information. Telephone contacts followed by a survey by questionnaire of nine steel mills will be performed. The questionnaire should include questions concerning the quantity and types of landfilled sludge and trash, oil contents, and method of transport and disposal. The fate of oil in landfills will have to be determined by using a test program. Plant visits should be made to inspect landfill facilities and to obtain samples of oily sludge and trash. Samples of storm-runoff at representative steel plant landfills must be taken to determine the oil concentration in discharges and the chemical and toxic properties. Local rainfall patterns must be considered in the study of runoff oil contents. The relative amount of oil washed or carried away by the runoff should be determined experimentally and in the field.

Included in the investigation of oil in landfilled sludge and trash should be review of available control and oil recovery methods. Methods of recovering the oil from sludge prior to disposal in landfills or of capturing oil in landfill runoff will be reviewed. Techniques to prevent oil from escaping the landfill and entering the environment should be investigated for oil that cannot be recovered.

10.2 Waste Oil Recovery and Reclamation

The second largest loss term identified in the study was oils reclaimed as fuel or lubricants. A few waste oil reclaimers were contacted and data regarding specific steel mill waste oils was collected. The increasing cost of virgin lubricants combined with more stringent wastewater discharge requirements is stimulating improved waste oil collection and recovery efforts by the steel industry. Rapid growth in the waste oil recovery and reclamation industry is predicted, in part, as a result of these efforts. The steel industry should be encouraged and possibly assisted in their attempts to increase waste oil collection and reclamation practices. Improved waste oil collection methods and practices are needed at some steel mills. An investigation of the most effective waste oil collection equipment and practices could be of use by the steel industry. The benefits and economics of recovering steel mill waste oil for reclamation as both fuel and lubricants should be reviewed. Environmental problems associated with the waste oil reclamation industry could also be investigated and a more comprehensive survey of waste oil reclaimers could be conducted. Air and water pollution and solid waste problems resulting from waste oil reclamation may increase as increasing quantities of waste oil are handled. As part of the waste oil reclamation investigation a review should be made of potential air pollution or equipment operating problems due to the combustion of reclaimed fuel containing metals and other impurities.

To obtain information and data necessary to evaluate steel plant waste oil recovery and reclamation the literature should be reviewed and both the steel industry and waste oil reclamation industry should be contacted. The literature search and review, performed at the beginning of the study, will provide background information and a guide to specific topics to be investigated in greater detail. Much information concerning waste oil reclamation efforts is available in recent literature.

Steel plants identified in the literature and previous industry studies as practicing good waste oil recovery and reclamation habits should be contacted for information. Waste oil reclamation processes and capabilities should also be reviewed by direct industry contact. A questionnaire for the steel industry, and a second questionnaire for the waste oil reclamation industry, should be prepared and mailed to the respective industries. Prior to mailing the questionnaire, telephone contacts should be made to identify knowledgeable and cooperative industry people. Plant visits to both steel mills and waste oil reclaimers are needed to collect data, inspect equipment, discuss operating practices and obtain a first-hand understanding of waste oil recovery and reclamation capabilities and problems.

Emphasis should be placed on the air and water pollution and solid waste problems resulting from waste oil reclamation. Methods of reducing or controlling pollution discharges should be identified and described. The benefits and drawbacks of recovering and reclaiming steel plant waste oil from an environmental standpoint should be evaluated.

10.3 Mill Scale Handling

Mill scales are known to contain significant quantities of oil. The collection, handling and treatment of mill scales in the steel industry, and the resulting environmental effects deserve additional study. Currently a wide variety of systems and practices are used by the industry for handling mill scales. Mill scale is produced in large quantities during rolling operations. At one steel mill producing 2.3×10^9 kg/yr (2.5×10^6 tons/yr) of raw steel, it is reported that approximately 113×10^6 kg/yr (125,000 tons/yr) of mill scale is generated. Mill scale, depending on the type of rolling mill and lubrication practices, can contain up to about 20 percent by weight oil. Typically oil contents of 0.1 to 1.0 percent are reported. Oily mill scale is undesirable for recycling to most sinter plants because of air pollution problems caused by volatized oil. It appears that the slow moving flame front encountered in sinter machines volatizes rather than combusts the oil. The concentration and nature of the hydrocarbons emitted as a result of sintered mill scale is currently unknown. Volatized oil can adversely affect air pollution control device performance and cause opacity problems and emission violations. Several steel mills currently stockpile for future recovery mill scales containing excessive amounts of oil. The amount of oil in mill scale that the sinter plant can handle varies from one steel mill to the next, depending primarily on the type of installed air pollution control equipment. The use of certain types of control devices, such as baghouses, precludes recycling mill scale containing significant amounts of oil.

An investigation of the entire oily mill scale problem is needed. Rates and quantities of mill scale generated by the various rolling mills and the oil content of these scales should be studied in more detail. The effect of improved scale pit design, incorporating oil recovery equipment, should be determined. Current practices employed by the steel mills for collecting and stockpiling or recycling mill scale need further investigation. Several factors must be evaluated as they are interrelated. For example, once oily mill scale is formed it becomes a potential problem. When stockpiled, oil picked up by surface runoff can become a water pollution problem. This potential water pollution problem requires additional study. When recycled to the sinter plant, air pollution (hydrocarbon emissions) becomes a problem. The overall impact resulting from either practice should be evaluated. A program to resolve one aspect of the problem while overlooking other aspects is unsatisfactory from both an environmental and industry point of view.

The steel industry is currently investigating methods of reclaiming the iron from oily mill scale. One approach involves washing the mill scale with solvent to remove the oil. Consideration of oil recovery is only secondary. Another approach involves adding chemicals to the scale pits to reduce the oil content of mill scales. Segregation of the very oily mill scales is currently practiced at some steel mills. Modification or replacement of sinter plant control equipment is considered at other plants. The potential environmental impacts of adapting these various alternatives should be determined.

A literature and industry survey is needed to obtain additional data regarding the quantities of mill scale produced. Current and planned methods of handling and recycling mill scale should be studied. Following a literature review, a program utilizing questionnaires sent to steel companies is needed. The removal of oil prior to sintering should be considered as well as sinter plant add-on control equipment capable of removing both particulates and the volatized oils introduced by the mill scale.

10.4 Hydrocarbon Emissions from the Steel Industry

Hydrocarbon emissions from the steel industry need to be studied in greater detail. The accuracy of the loss terms related to volatized oil is questionnable and other potential hydrocarbon emission sources may exist at steel mills. It was estimated in Section 9.3 that 2.3 x 10^6 kg/month (5 x 10^6 lb/month or 30,000 tons/yr) of hydrocarbons are emitted by the steel industry as a result of volatized lubricants. Also, most steel production occurs in areas with recognized air quality problems. The contribution of steel industry hydrocarbon emissions to oxidant formation should be determined. The quantity of hydrocarbons emitted should be verified, and the nature of these hydrocarbon emissions should be determined. The increased emphasis or shift to wastewater recycle could lead to greater hydrocarbon emissions by the steel industry. Projections should be made of future hydrocarbon emissions resulting from zero wastewater discharge requirements. Air pollution control devices capable of reducing hydrocarbon emissions from sinter plants handling mill scale need to be identified, also.

A review is needed of available literature and previous EPA studies related to hydrocarbon emissions from the steel industry. The relative magnitude of steel plant hydrocarbon emissions in air sheds with recognized hydrocarbon/oxidant air quality problems should be determined. To evaluate the magnitude of steel plant hydrocarbon emissions, emission factors for the equipment or processes responsible for these emissions is needed. Currently AP-42 Compilation of Air Pollution Emission Factors does not include any hydrocarbon emission factors for the iron and steel industry. The fact that potentially significant hydrocarbon emissions are encountered in the steel industry and nearly all steel plants are located in or near large population centers necessitates an evaluation of steel mill hydrocarbon emissions. A more accurate estimate or data regarding steel plant hydrocarbon emissions or usable iron and steel industry hydrocarbon emission factors would be very useful to federal, state and local air quality planning agencies.

A review and evaluation of available hydrocarbon emission control technology is needed. The performance and costs of such control equipment should be determined. The ability of a control system capable of minimizing air pollution emissions without resulting in additional water pollution or solid waste disposal problems should be evaluated. Control equipment vendors and users should be contacted for design, operating and cost data. Growth predictions for the iron and steel industry, combined with the use of improved control technology and practices should be used to project future steel industry hydrocarbon emissions.

As part of the steel industry hydrocarbon emissions evaluation recommendations for a source testing program could be developed and available steel mill hydrocarbon source test data compiled and summarized.

10.5 Wastewater Sampling, Analysis and Monitoring for Total Oil and Grease

The representativeness of wastewater samples for total oil and grease determination is questioned by both water pollution control agency and industry representatives. The selection of the sampling site and design of the sampling apparatus can strongly affect the sample obtained. The sampling difficulties are primarily caused by the tendency of oils and greases to float and hence be nonuniformly distributed in the wastewater stream. Current sampling practices rely on rapidly sinking a wide mouth glass jar to obtain a representative sample. Uniform sampling apparatus design has not been encouraged and a determination of the influence of apparatus design has not been performed.

Total oil and grease analysis procedures also need to be evaluated. The two most common methods (Storet Nos. 00550 and 00556) utilize Freon 113 as a reagent to extract oils and greases. One method involves the use of Soxhlet extractors to remove the oils and greases while the other method employs large separatory funnels. Both methods are reported to be capable of measuring total oil and grease concentrations in the range from 5 to 1000 mg/l. The precision and accuracy of the two analysis methods were determined by dosing a one liter portion of sewage with 14.0 mg of a mixture of #2 fuel oil and Wesson Oil. No data concerning tests performed with industrial wastewater samples dosed with typical lubricating oils and greases, hydraulic fluids, or rolling oils and fats was available. In addition, most steel mill waste samples are reported to contain from 0 to 5 mg/l of total oil and grease; below the recommended range of detection of the two analysis methods.

An investigation of wastewater sampling, analysis and monitoring methods for total oil and grease content should consist primarily of an experimental program. A steel plant must be located where a field sampling program can be carried out. At a given wastewater discharge (or in-plant wastewater stream) sampling location a determination must be made of the precision (the degree of agreement of repeated measurements of the same property) of the grab sampling method. An effort to develop a repeatable sampling procedure and apparatus must be made. The influence of sample apparatus parameters, such as the sinker weight and diameter and size of sample jar mouth, and wastewater stream parameters, such as depth and stream velocity, must be evaluated. Once a repeatable sampling apparatus is developed a study to evaluate the representativeness of the grab sample to the actual wastewater stream should be determined. Also, an evaluation is needed of the frequency of grab sampling necessary to determine average wastewater oil and grease content. Often only one or two grab samples are taken per month.

A laboratory program to determine the accuracy and precision of the analysis methods (Storet Nos. 00550 and 00556) is also needed. Oil free industrial wastewater samples should be dosed with known quantities of typical lubricating oils and grease and then analyzed. Since steel plant wastewater discharges often contain from 0 to 5 mg/l of total oil and grease the accuracy of the two analyses methods within this range should be evaluated.

Several continuous monitoring and portable sampling devices have been developed recently for total oil and grease measurement. Currently, little information is available concerning the application of these devices on industrial wastewater streams. An investigation of wastewater oil and grease sampling and analysis procedures and methods, should include a review of the currently available continuous or portable monitors. Designers and vendors of monitoring and sampling devices should be contacted and requested to provide specifications for available devices and lists of where such devices have been installed. Calls to users of such equipment should be made to verify performance.

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APPENDIX A

Process Lubrication Areas For An Integrated Steel Mill

PROCESS LUBRICATION AREAS FOR AN INTEGRATED STEEL MILL

1. ORE AND LIMESTONE HANDLING EQUIPMENT

Car Dumpers, Conveyors, Bridge Bearings, Track Wheel Journal Box Roller Bearings - General Purpose EP Grease.

Open Gears - Graphite or Molybdenum Disulfide Grease.

Cables, Closed Gears - Mild EP Oil.

Electric Motors, Roller Bearings - Rust and Oxidation Inhibited Bearing Greases.

2. COKE BATTERIES AND COAL HANDLING EQUIPMENT

Larry and Quench Car Bearings - Oxidation Resistant Grease.

Conveyor Idler, Coke Guides - General Purpose Grease.

Reduction, Worm & Enclosed Spur Gears - Mild EP Gear Oil.

Coal Elevator, Charger - EP Gear Oil.

Door Hinges, Latches - High Temperature EP Grease.

Hydraulic Pusher - Fire Resistant Hydraulic Fluid.

Locomotive - Diesel EMD Oil.

Rollers, Bearings, Rods - Extra Duty Lithium EP Grease.

3. BLAST FURNACE

Skip Hoist Sheaves, Skip Car Wheels - NGLI #2 EP Grease.

Hoist Cables - Graphite or Molybdenum Disulfide Grease.

Electric Motors - Rust and Oxidation Inhibited Ball and Roller Bearing Grease.

Reduction Gears - Mild EP Oil.

Furnace Bells - NGLI #1 EP Grease.

Hot Metal and Slag Cars - General Purpose EP Grease.

Distributor Grease Seals - Extra Duty Lithium EP Grease.

Torpedo Cars - High Temperature EP Grease.

4. COKE BY-PRODUCT PLANT

Fans, Blowers - Rust and Oxidation Inhibited Turbine Oil.

5. METAL MIXER

Tilting Mechanism Motor - Bearing Grease.

Worm Gears, Tilting Screw Gears - Mild EP Oil.

6. STEEL FURNACES

A. Basic Oxygen Process

Gear Train - Mild EP Gear Oil.

Trunnion Bearings - Extreme Temperature Grease or Molybdenom Disulfide Greases.

Tilting Mechanism - Low Viscosity EP Oil.

B. Electric Arc Furnace

Tilting Mechanism, Electrodes - Fire Resistant Hydraulic Fluids, i.e. (Water-in-Oil Emulsions, Water-Glycol Fluids, Phosphate Ester Fluids, Phosphate Ester-Mineral Oil Fluids, & Halogenated Fluids), All Invert Emulsions.

Tilting Gears - Mild EP Gear Oil.

Electrode Guides, Drive and Clutches - High Temperature EP Grease.

C. Open Hearth Furnace

Charging Machine Ram Induction Gears - Mild EP Oil.

Ram Motors, Electric Motors - Ball Grease.

Charging Box Wheels - High Temperature EP Grease.

Door Lifter Worm Gears - Mild EP Gear Oil.

Fan Bearings - High Viscosity Turbine Oil.

7. CONTINUOUS CASTING

Mold Coating - Rape Seed Oil.

Casting Unit Gears - Mild EP Oil.

7. CONTINUOUS CASTING (Con't)

Roll Bearings - General Purpose EP Grease.

Pinch Roll & Cut Off Torch Systems - Fire Resistant Hydraulic Fluids (Oil-in-Water Emulsions or Glycol Fluids).

8. SCARFER

Rollers and Bearings - High Viscosity Mineral Oil or Medium Viscosity Spray Oil.

Hydraulic System - Phosphate Esters.

9. REHEAT FURNACES

Doors, Rollers, Rails - Temperature Resistant Lithium or Lime Base #2 EP Grease.

10. SOAKING PITS

Crane Reduction Gears - Mild EP Gear Oil.

Electric Motor Roller Bearings - Ruse and Oxidation Inhibited Grease.

Door Equipment - Phosphate Ester Hydraulic Fluids.

Wheel Bearings - Extreme Temperature Grease.

11. PRIMARY ROLLING MILLS (Bloom, Slabs & Billets)

Roll Stands, Mill Table Bearings, Mill Spindles - Water and Shear Resistant EP Grease.

Screw Down - Medium Viscosity Mild EP Oil, Low Viscosity Roll Neck Grease.

Pinion Stands, Table Gears - Low Viscosity EP Oil.

Roll Balance System - Fire Resistant Hydraulic Oil, Invert Emulsions.

Roll Neck Bearings - Medium Viscosity Spray Oil.

12. SECONDARY ROLLING MILLS (Rail, Structural, Plate, Merchant Bar, Hot Strip-Sheet, Strip, Tin Plate, Rod, Wire, Tube.)

Tensioning and Coiler Reel Mandrels, Roll Bearings, Table Roll Bearing - General Purpose EP Grease.

12. SECONDARY ROLLING MILLS (Con't)

Back Up Roll Neck Bearings - Mineral Oil With Water Separation Properties.

Drives - Mild EP Gear Oil.

Screwdown - Medium Viscosity Mild EP Gear Oil, Low Viscosity, Roll Neck Grease.

Pinion Stand Bearings and Gears - Medium Viscosity EP Oil.

Roll Balance System - Fire Resistant Inhibited Hydraulic Oi .

Coiler Drive - Mild EP Gear Oil.

Mandrel Components - General Purpose EP Grease.

13. SINTERING AND PELLETIZING PLANT

Chains, Wire Ropes, Gear Cases, Reducers - Mild EP Oil.

Retarder Bearing, Breaker Shaft, Drive Shaft, Conveyors, Feeding Machines - General Purpose EP Grease.

Couplings - General EP or Adhesive Sodium Base Greases.

Pallet Wheel Bearings, Rails, Sinter Screen Bearings - Extreme Temperature Greases.

Ore Crushers, Balling Machine - Mild EP Oil With Thermal and Oxidation Inhibitors.

Seals - #2 Lithium Base EP Greases, and Asphaltic Compounds at High Temperatures.

14. AIR AND WATER CIRCULATION

Turbo Fans, Turbines - Paraffinic Rust and Oxidation Inhibited Oils.

Steam Engines - Mineral Cylinder Oil.

Pump Gear Drives - Mild EP Oil.

Electric Motors - Rust and Oxidation Inhibited Grease or Oil (150-300 SUS).

Water Pump Bearings - Water Resistant Greases or High Quality Mineral Oil.

15. PICKLING AND GALVANIZING

Rolls, Reels - High Viscosity Mineral Oils.

Uncoilers - Low Viscosity Mineral Oil Hydraulic Fluid.

16. <u>ANNEALING LINES</u>

Continuous Lines - Low Viscosity EP Misting Oils.

Batch Lines - High Temperature EP Grease.

17. <u>SENDZIMIR ROLLING</u>

Fine Finishes, Heavy Gage Steel - Low Viscosity Mineral Oil (70-150 SUS).

Stainless Steel, Sheet & Plate - Fatty Polar Type Oils.

Carbon & Silicon Steels - Soluble Oil Emulsions, Paraffinic Slushing Oils.

Tin Plate - Palm Oil or Palm Oil Blends.

18. <u>STORAGE</u>

Protective Coatings -

Indoor - Low Viscosity Mineral Oil in Some Cases With Polar Additives, Inhibited Petroleum Oils.

Outdoor - Heavy Petroleum or Asphaltic Coatings, Petroleum, Varnish Coating.

APPENDIX B

Oil and Grease in Wastewater Analysis Methods

OIL AND GREASE, Total, Recoverable
(Soxhlet Extraction)

STORET NO. 00550

1. Scope and Application
   1.1 This method includes the measurement of Freon extractable matter from surface and saline waters, industrial and domestic wastes. It is applicable to the determination of relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related matters.
   1.2 The method is not applicable to measurement of light hydrocarbons that volatilize at temperatures below 70°C. Petroleum fuels from gasoline through #2 fuel oil are completely or substantially lost in the solvent removal operation.
   1.3 The method covers the range from 5 to 1000 mg/l of extractable material.
2. Summary of Method
   2.1 The sample is acidified to a low pH (<2) to remove the oils and greases from solution. After they are isolated by filtration, they are extracted with Freon using a Soxhlet extraction. The solvent is evaporated from the extract and the residue weighed.
3. Definitions
   3.1 The definition of grease and oil is based on the procedure used. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the material measured and interpretation of results.
4. Sampling and Storage
   4.1 A representative 1 liter sample should be collected in a wide-mouth glass bottle. If analysis is to be delayed for more than a few hours, the sample is preserved by the addition of 5 ml H_2SO_4 or HCl (6.1) at the time of collection.
   4.2 Because losses of grease will occur on sampling equipment, the collection of a composite sample is impractical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentration over an extended period.
5. Apparatus
   5.1 Extraction apparatus consisting of:
      5.1.1 Soxhlet extractor, medium size (Corning No. 3740 or equivalent).
      5.1.2 Soxhlet thimbles, to fit in Soxhlet extractor, (5.1.1).
      5.1.3 Flask, 125 ml (Corning No. 4100 or equivalent).

5.1.4 Condenser, Allihn (bulb) type, to fit extractor.

5.1.5 Electric heating mantle.

5.2 Vacuum pump, or other source of vacuum.

5.3 Buchner funnel, 12 cm.

5.4 Filter paper, Whatman No. 40, 11 cm.

5.5 Muslin cloth discs, 11 cm (muslin cloth available at sewing centers). The muslin discs are cut to the size of the filter paper and pre-extracted with Freon before use.

6. Reagents

6.1 Sulfuric acid, 1:1. Mix equal volumes of conc. H_2SO_4 and distilled water. (Conc. hydrochloric acid may be substituted directly for conc. sulfuric for this reagent.)

6.2 Freon 113, b.p. 48°C, 1,1,2-trichloro-1,2,2-trifluoroethane. At this time, reagent grade Freon is not commercially available. Freon 113 is available from E. I. DuPont de Nemours, Inc., and its distributors in 5-gallon cans. It is best handled by filtering one gallon quantities through paper into glass containers, and maintaining a regular program of solvent blank monitoring.

6.3 Diatomaceous - silica filter aid suspension, 10 g/l in distilled water.

NOTE: Hyflo Super-Cel (Johns-Manville Corp.) or equivalent is used in the preparation of the filter aid suspension.

7. Procedure

7.1 In the following procedure, all steps must be rigidly adhered to if consistent results are to be obtained.

7.2 Mark the sample bottle at the water meniscus for later determination of sample volume. If the sample was not acidified at the time of collection, add 5 ml sulfuric acid or hydrochloric acid (6.1) to the sample bottle. After mixing the sample, check the pH by touching pH-sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid if necessary.

7.3 Prepare a filter consisting of a muslin cloth disc overlaid with filter paper. Place the assembled filter in the Buchner funnel and wet the filter, pressing down the edges to secure a seal. With vacuum on, put 100 ml of the filter aid suspension through the filter and then wash with three 100 ml volumes of distilled water. Continue the vacuum until no more water passes through the filter.

7.4 Filter the acidified sample through the prepared filter pad under vacuum and continue the vacuum until no more water passes through the filter.

7.5 Using forceps, transfer the filter paper and all solid material on the muslin to a watch glass. Wipe the inside and cap of the sample bottle and the inside of the

Buchner funnel with pieces of filter paper soaked in Freon to remove all oil film. Fold the pieces of filter paper and fit them into an extraction thimble. Wipe the watch glass in a similar manner and add the filter paper and all solid matter to the thimble.

7.6 Fill the thimble with small glass beads or glass wool, and dry in an oven at 103°C for *exactly* 30 minutes.

7.7 Weigh the distilling flask (pre-dried in oven at 103°C and stored in desiccator), add the Freon, and connect to the Soxhlet apparatus in which the extraction thimble has been placed. Extract at the rate of 20 cycles per hour for four hours. The four hours is timed from the first cycle.

7.8 Evaporate the solvent from the extraction flask in a water bath at 70°C. Dry by placing the flask on a covered 80°C water bath for 15 minutes. Draw air through the flask by means of an applied vacuum for 1 minute.

7.9 Cool the flask in desiccator for 30 minutes and weigh.

8. Calculation

8.1 $\text{mg/l total grease} = \frac{R-B}{V}$

where:

R = residue, gross weight of extraction flask minus the tare weight, in milligrams.

B = blank determination, residue of equivalent volume of extraction solvent, in milligrams.

V = volume of sample, determined by refilling sample bottle to calibration line and correcting for acid addition if necessary, in liters.

9. Precision and Accuracy

9.1 The three oil and grease methods in this manual were tested by a single laboratory (MDQARL) on a sewage. This method determined the oil and grease level in the sewage to be 14.8 mg/l. When 1 liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 88% with a standard deviation of 1.1 mg.

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OIL AND GREASE, Total, Recoverable
(Separatory Funnel Extraction)

STORET NO. 00556

1. Scope and Application

1.1 This method includes the measurement of Freon extractable matter from surface and saline waters, industrial and domestic wastes. It is applicable to the determination of relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related matter.

1.2 The method is not applicable to measurement of light hydrocarbons that volatilize at temperatures below 70°C. Petroleum fuels from gasoline through #2 fuel oils are completely or substantially lost in the solvent removal operation.

1.3 Some crude oils and heavy fuel oils contain a significant percentage of residue-type materials that are not soluble in Freon. Accordingly, recoveries of these materials will be low.

1.4 The method covers the range from 5 to 1000 mg/l of extractable material.

2. Summary of Method

2.1 The sample is acidified to a low pH (<2) and serially extracted with Freon in a separatory funnel. The solvent is evaporated from the extract and the residue weighed.

3. Definitions

3.1 The definition of grease and oil is based on the procedure used. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the material measured and interpretation of results.

4. Sampling and Storage

4.1 A representative sample of 1 liter volume should be collected in a glass bottle. If analysis is to be delayed for more than a few hours, the sample is preserved by the addition of 5 ml H_2SO_4 or HCl (6.1) at the time of collection.

4.2 Because losses of grease will occur on sampling equipment, the collection of a composite sample is impractical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentration over an extended period.

5. Apparatus

5.1 Separatory funnel, 2000 ml, with Teflon stopcock.

5.2 Vacuum pump, or other source of vacuum.

5.3 Flask, distilling, 125 ml (Corning No. 4100 or equivalent).

5.4 Filter paper, Whatman No. 40, 11 cm.

6. Reagents

6.1 Sulfuric acid, 1:1. Mix equal volumes of conc. H_2SO_4 and distilled water. (Conc. hydrochloric acid may be substituted directly for conc. sulfuric for this reagent).

6.2 Freon 113, b.p. 48°C, 1,1,2-trichloro-1,2,2-trifluoroethane. At this time, reagent grade Freon is not commercially available. Freon 113 is available from E. I. DuPont de Nemours, Inc. and its distributors, in 5-gallon cans. It is best handled by filtering one gallon quantities through paper into glass containers, and maintaining a regular program of solvent blank monitoring.

6.3 Sodium sulfate, anhydrous crystal.

Procedure

7.1 Mark the sample bottle at the water meniscus for later determination of sample volume. If the sample was not acidified at time of collection, add 5 ml sulfuric acid or hydrochloric acid (6.1) to the sample bottle. After mixing the sample, check the pH by touching pH-sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid if necessary.

7.2 Pour the sample into a separatory funnel.

7.3 Add 30 ml Freon (6.2) to the sample bottle and rotate the bottle to rinse the sides. Transfer the solvent into the separatory funnel. Extract by shaking vigorously for 2 minutes. Allow the layers to separate.

7.4 Tare a distilling flask (pre-dried in an oven at 103°C and stored in a desiccator), and filter the solvent layer into the flask through a funnel containing solvent moistened filter paper.

NOTE: An emulsion that fails to dissipate can be broken by pouring about 1 g sodium sulfate (6.3) into the filter paper cone and draining the emulsion through the salt. Additional 1 g portions can be added to the cone as required.

7.5 Repeat (7.3 and 7.4) twice more, with additional portions of fresh solvent, combining all solvent in the distilling flask.

7.6 Rinse the tip of the separatory funnel, the filter paper, and then the funnel with a total of 10-20 ml Freon and collect the rinsings in the flask.

7.7 Evaporate the solvent from the extraction flask in a water bath at 70°C. Dry by placing the flask on a covered 80°C water bath for 15 minutes. Draw air through the flask by means of an applied vacuum for 1 minute.

7.8 Cool in desiccator for 30 minutes and weigh.

8. Calculation

8.1 mg/l total oil and grease = $\frac{R-B}{V}$

where:

R = residue, gross weight of extraction flask minus the tare weight, in milligrams.

B = blank determination, residue of equivalent volume of extraction solvent, in milligrams.

V = volume of sample, determined by refilling sample bottle to calibration line and correcting for acid addition if necessary, in liters.

9. Precision and Accuracy

9.1 The three oil and grease methods in this manual were tested by a single laboratory (MDQARL) on a sewage. This method determined the oil and grease level in the sewage to be 12.6 mg/l. When 1 liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 93% with a standard deviation of 0.9 mg.

Bibliography

1. Standard Methods for the Examination of Water and Wastewater, 13th Edition, p 254, Method 137 (1971).

2. Blum, K. A., and Taras, M. J., "Determination of Emulsifying Oil in Industrial Wastewater", JWPCF Research Suppl. *40*, R404 (1968).

APPENDIX C

A Practical Guide for Lubricating a Fully Integrated Steel Mill

Detailed Oil, Grease and Hydraulic Fluid Usage Data By Plant Area and Application
(page C-13)

Monthly Lubricant Usage Data Summary
(page C-25)

Provided by
Joseph Lykins

A PRACTICAL GUIDE FOR LUBRICATING A FULLY INTEGRATED STEEL MILL

By

Joseph D. Lykins

A. Auxiliary Equipment

1. Electric Motor Bearings
   - Oil Lubricated ------------- Rust & Oxidation Inhibited Oils
   - Grease Lubricated ---------- Premium Quality Ball & Roller Bearing Greases

2. Air Compressors ------------------ Rust & Oxidation Inhibited Oils

3. Water Pumps
   - Gear Drives --------------- 1000 SSU (215.8 cSt) Vis. @ 100°F. Sul/Phos EP Gear Oil
   - Bearings
     - Oil Lubricated ---------- Rust & Oxidation Inhibited Oils
     - Grease Lubricated ------- Premium Quality, Water Resistant, Ball & Roller Bearing Grease

4. Steam Turbines
   - Direct Connected
     - Bearings & Govenors ----- 150 SSU (31.9 cSt) or 215 SSU (46.2 cSt) Vis. @ 100°F. R&O Oil
   - Geared Turbines
     - Bearings & Gears -------- 315 SSU (68.0 cSt) or 465 SSU (100.4 cSt) Vis. @ 100°F. R&O Oil

5. Blowing Engines
   - Steam Engines
     - Saturated & Superheated Steam System ----------- 4650 SSU (1003.9 cSt) Vis. @ 100°F., Min. VI-80, Cylinder Oil + 4-6% Acidless Tallow Compounding
     - Non-Condensing Steam System------------ 2150 SSU (464.3 cSt) Vis. @ 100°F., Min. VI-80, Cylinder Oil + 8-10% Acidless Tallow and Degras Compounding

6. Turbo-Blowers ----------------- SAE 40 or 50 HD Motor Oil

7. Gas Engines

Crankcase ----------------	SAE 40 or 50 HD Motor Oil
Engine Parts -------------	150 SSU (31.9 cSt) and 315 SSU (68.0 cSt) Vis. @ 100°F. Red Engine Oil

B. Blast Furnaces

1. Bell Top Distributor, Skip Hoist, Skip Cars, and General Grease Lubrication ----	Either of the following:- Lithium 12-Hydroxy Stearate EP No.1; Aluminum Complex EP No.1; Calcium Complex EP No.1; Bentone EP No.1
2. Reduction Gears (Hoist) ----------	2150 SSU (464.3 cSt) Vis. @ 100°F. Sul/Phos EP Gear Oil
3. Wire Rope ------------------------	Follow Wire Rope Mfg. Recommendations
4. Hot Metal & Slag Car Wheels ------	Bentone EP Grease, or 2150 SSU (464.3 cSt) Vis. @ 100°F. Sul/Phos EP GearOil, where oil is required.
5. Couplings -----------------------	Sodium Base Grease No.1

C. Limestone, Coke, and Ore Handling Equipment

1. Hoists

Electric Motor Bearings	
Oil Lubricated ----------	R&O Inhibited Oils
Grease Lubricated -------	Premium Quality Ball & Roller Bearing Grease
Worm and Helical Gears -------	2150 SSU (464.3 cSt) Vis. @ 100°F. Sul/Phos EPGear Oil
Open Gears --------------------	Solvent Cut-Back Gear Shield Base Oil Vis. @ 210°F. of 5000/10000 SSU (1072.0/2144.3 cSt) Depending on ambient temperature conditions
Wire Rope -------------------	Follow Wire Rope Mfg. Recommendations.
Journal Boxes (Track Wheels) -	"Sta-Pax" With Oil, or "Wool Yarn Elastic"
General Grease Lubrication --	Either of the following:- Lith. 12-Hyd. Stearate EP No.1 or; Aluminum Complex EP "; Calcium Complex EP "; Calcium EP "

D. Sintering and Pelletizing Equipment

1. Enclosed Gear Drives	2150 SSU (464.3 cSt) or 7000 SSU (1511.2 cSt) Vis. @ 100°F. Sul/Phos EP Gear Oil Depending on type of gears and ambient temperature.
2. General Grease Lubrication	Either of the following:- Lith. 12-Hyd. Stearate EP Aluminum Complex Calcium Complex EP Calcium EP
3. Chains	EP Gear Oil
4. Centralized Grease System	Same as 2. above.
5. Bull, Retarder and Breaker Cams Gear Cases	2150 SSU (464.3 cSt) Vis. @ 100°F. Sul/Phos EP Gear Oil
6. Shaker Screen Conveyor Pinion Gears and Bearings	715 SSU (154.4 cSt) Vis. @ 100°F. EP Gear Oil
Bearings (Mist Lubricated)	1000 SSU (215.8 cSt) Vis. @ 100°F. EP Mist Oil
7. Sinter Cooler Speed Reducers and Gear Cases	1500-2150 SSU (323.8-464.3 cSt) Vis. @ 100°F. EP Gear Oil
8. Fan Bearings	715 SSU (154.4 cSt) Vis. @ 100°F. R&O Oil

E. Coke Oven Equipment

1. Electric Motor Bearings	Premium Quality Ball & Roller Bearing Grease
2. Air Compressors	R&O Inhibited Oil
3. Reduction Drives	1500-2150 SSU (323.8-464.3 cSt) @ 100°F. EP Gear Oil
4. General Grease Lubrication	Either of the following:- Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium EP
5. Chains	3150 SSU (680.1 cSt) @ 100°F. EP Gear Oil
6. Coke Quenching Car Wheels	"Sta-Pax" or "Wool Yarn Elastic" with EP Oil
7. Coal Elevator and Charger Worm Gears	2150 - 3150 SSU (464.3 - 680.1 cSt) EP Gear Oil

8. Coke Oven Pusher and Door Machines

Door Latches -------------------- Bentone Grease No.1

Hydraulics ---------------------- Water Glycol or Inverted Emulsions, Depending on the type of pump in service

F. Hot Metal Cars

1. Wheel Bearings

Antifriction Bearings ------------ Bentone Grease No.1, or 2150 SSU (464.3 cSt) Vis. @ 100°F. Sul/Phos EP Oil, where oil is required.

Plain Bearings ------------------ "Sta-Pax" or "Wool Yarn Elastic" with EP Oil

G. Mixers

1. Mixer Rollers ------------------ Either of the following:-
Lith. 12-Hyd. Stearate EP
Aluminum Complex EP
Calcium Complex EP
Calcium EP

2. Tilting Mechanism

Motor Bearings

Grease Lubricated ------------ Premium Roller Brg. Grease

Oil Lubricated -------------- 315-700 SSU (68.0-151.0 cSt) @ 100°F. R&O Oil

Worm Gear Drives --------------- 2100 SSU (453.4 cSt) Vis. @ 100°F. - Compounded Cylinder Oil or Sul/Phos EP Gear Oil

Open Gears --------------------- Solvent Cut-Back Gear Oil.

H. Open Hearth Equipment

1. Track Wheels -------------------- Either of the following:-
Lith. 12-Hyd. Stearate EP
Aluminum Complex EP
Calcium Complex EP
Calcium EP

2. Induced-Draft Fans

Bearings ------------------------ 700 SSU (151.0 cSt.) Vis. @ 100°F. R&O Oil

Electric Motor Brg. ------------- High Temp. Premium Roller Bearing Grease

3. Door Lifting Drives

Motor Brgs. -------------------- Premium Roller Brg. Grease

Worm Gear Drives --------------- 2150 SSU (464.3 cSt.) Vis. @100°F. Sul/Phos EP Gear Oil, or Compounded Cylinder Oil

Enclosed Gears ----------------- 2150 SSU (464.3 cSt.) Vis. @ 100°F. Sul/Phos. Gear Oil

I. Soaking Pitts

1. Pit Covers

Enclosed Gears ---------------	2150 SSU (464.3 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil
Open Gears -----------------	Solvent Cut-Back Gear Shield

2. Lifting Mechanism

Wheel Bearings --------------	Either of the following:- Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium EP

J. Basic Oxygen Furnace (BOF)

1. Rotating, Charging, and Dumping Machine

Tilting Mechanism Gear Train-	700 SSU (151.0 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil
Trunion Brg. Antifriction ---	Either of the following:- Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium EP Bentone EP
Charging Machine ------------	Either of the following:- Phosphate Ester Hyd. Fluid Water Glycol Hyd. Fluid Inverted Emulsion Hyd. Fluid, depending on the type of pump in service.

2. Oxygen Lance

Hoist Bearings---------------	High Temperature Grease Either of the following:- Bentone Aluminum Complex Calcium Complex Lithium Complex

3. Enclosed Gears ------------------	2150 SSU (464.3 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil
4. Open Gears ----------------------	Solvent Cut-Back Gear Shield
5. General Grease Lubrication ------	Either of the following:- Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium EP

K. Basic Oxygen Bottom Blown Process "Q"-BOF -------------------------------- Lubrication is the same as that for BOF Furnace, except that no Oxygen Lance is required

L. Argon Oxygen Decarbonization Process "AOD"

1. Tilting Mechanism ------------------ 1050 SSU (226.7 cSt.) Vis. @ 100°F. R&O Oil, or where required, 1050 SSU (226.7 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil

2. Trunion Bearings ------------------ Either of the following:-
Lith. 12-Hyd. Stearate EP
Aluminum Complex EP
Calcium Complex EP
Calcium EP
Bentone EP

M. Electric Furnace Process

1. Electrodes

Tilting Mechanism Gear Train ---- 1050 SSU (226.7 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil

Guides, Swing Sheaves, Cylinder End Connections, and General Grease Lubrication -------------- Either of the following:-
Lith. 12-Hyd. Stearate EP
Aluminum Complex EP
Calcium Complex EP
Calcium EP
Bentone EP

2. Swinging Roof and Furnace Tilting Hydraulic System ------------------ Phosphate Ester Hyd. Fluid
Water Glycol Hyd. Fluid
Inverted Emulsion Hyd. Fluid
depending on the type pump in service.

3. Door Hoist

Worm Gear Reducer -------------- 2150 SSU (464.3 cSt.) Vis. @ 100°F. Sul/Phos EP Gear Oil

4. Air Compressor ------------------- R&O Oil.

N. Electric Furnace Anti-Polution Equipment

1. Ash System

Blowers ------------------------ 715 SSU (154.4 cSt.) Vis @ 100°F. R&O Oil

Rotary Feeds (Gear Motors) ----- 315 SSU (68.0 cSt.) Vis. @ 100°F. R&O Oil

Flexible Couplings ------------- Lith. 12-Hyd. Stearate EP or Sodium EP Grease No.1 Consistency

N.(Continued)

2. Lime and other Additives to Slag

Despensing Motors ----------------	215 SSU (40.2 cSt.) Vis @ 100°F. R&O Oil
Metering Motor Gear Reducers & Blowers ----------------------	715 SSU (154.4 cSt.) Vis @ 100°F. R&O Oil

3. Water Filters

Worm Gear Drives --------------	2150 SSU (464.3 cSt.) Vis @ 100°F. Sul/Phos EP Gear Oil

4. Exhaust and Repressuring Fans

Motor and Fan Bearings --------	Grease Lubricated Bearings, Premium Ball & Roller Bearing Grease, or for Oil Lubricated Bearings, 715 SSU (154.4 cSt.) Vis @ 100°F. R&O Oil.

O. Continuous Casting

1. Gear Drives -------------------	1500 & 2150 SSU (323.8 & 464.3 cSt.) Vis @ 100°F. Sul/Phos EP Gear Oil
2. Roll Bearings -----------------	Either of the Following:- Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium EP Bentone EP all No.1 Consistency Grease
3. Hydraulic Systems---------------	Phosphate Ester Hyd. Fluid Water Glycol Hyd. Fluid Inverted Emulsion Hyd. Fluid depending on the type pump in service.

P. Rolling Mill Equipment

Blooming & Slabbing Mills, Hot Strip Mills, Cold Reduction Mills, Temper Mills, Bar & Rod Mills, Structural Shape Mills, and Rail Mills all use the same or similar type equipment and therefore are classed under this general heading, without distinction.

1. Plain, Oil Film Type, Roll Neck Bearings -------------------

Note:- These bearings are usally of the high tin base babbit or "Asarcaloy" bearing metal type and are lubricated by circulating oil systems. Due to the large quantity of water involved, the oil used must have good demulsibility characteristics as measured by the ASTM D-2711 test for demulsibility of oils.

R&O Oils having the following Viscosities @ 100°F. depending on the loads, speeds, and mill temperatures involved :-

SSU	cSt.
715	154.4
1000	215.8
1250	269.9
1500	323.8
1750	377.8
2150	464.3
2450	528.9

2. Antifriction Type Roll Neck Bearings (Backup and Work Rolls)	
Grease Lubricated (Centralized System) -	Either of the following:-
Note: The NLGI consistency required will depend on the ambient temperature and/or the pumpability of the grease, usually, 0 grade in winter and 1 grade in summer.	Lith. 12-Hyd. Stearate EP Aluminum Complex EP Calcium Complex EP Calcium Lead EP Bentone EP
Mist Lubrication ----------------------	Special EP Mist Oil
3. Plain Babbitt and Bronze Grid Type Roll Neck Bearings	
Hand Packed ----------------------------	Block Grease (usually contains Graphite or other Solid Lubricants)
Grease Lubricated (Centralized System) -	Same as above - Anti-friction Type
Spray Lubricated ----------------------	Solvent Cut-Back Gear Shield or 7000/10000 SSU (1511.2/2158.9 cSt.) Vis @ 100 F. Oil
4. Fabric-Plastic Plain Roll Neck Bearings Generally used on Blooming, Skelp, and Bar & Rod Mills ----------	Combination of EP Grease (as above) and Cold, Clean Water
5. Spindle Bearings Grease Lubricated ------------------	Special Type Grease :- Base Grease either, Lith. 12-Hyd. Stearate, EP, or Aluminum Complex EP containing 3-5% Molybdenum Di-sulfide, 1% Graphite, and High Molecular Weight Polymers
6. Screw Downs, Mill Screws & Nuts -------	2150-3150 SSU (464.3-[illegible] cSt.) Vis @ 100°F. Sul/Phos EP Gear Oil, or equivalent Leaded Gear Oil
7. Pinion Stands & Edger Roll Drives ------------------------------	Sul/Phos EP Gear Oil, the viscosity dependent on the Gear Size, Speed, and Operating Temperature

Vis @ 100°F. SSU	Vis @ 100°F. cSt.
1000	215.8
1500	323.8
2150	464.3

P. (Continued)

8. Mill Table Gears --------------------	1500-2150 SSU (323.8-464.3 cSt.) Vis @ 100°F. Sul/Phos EP Gear Oil
9. Roll Changing Rigs Skid Shoes-----------------------	NLGI No. 2 Grease containing 3-5% Molybdenum Disulfide
10. Hydraulic Accumulators	
Plungers -----------------------	Graphited Grease
Roll Balance System Fluid ------------------------	5% Soluble Oil in Water, or an Inverted Emulsion Fluid
11. General Grease Lubrication-----------	Either of the following:- Lith.12-Hyd. Stearate EP; Aluminum Complex EP; Calcium Complex EP; Calcium EP

Q. Sendzimir (cluster) Mills

1. Common Lubricant for Roll Bearings, Internal Gears, and Rolling Oil (for the reduction of Strip)

Mineral Oil Type ------------------ For Normal Speeds & Pressures -	105 SSU (21.7 cSt.) Vis @ 100°F., Naphthenic Pale Oil
For High Speeds & Pressures ---	105 SSU (21.7 cSt.) Vis @ 100°F., Naphthenic Pale Oil plus Degras and EP additives
Soluble Oil Type ----------------	Heavy Duty, Petroleum Sulfonate Type Soluble Oil. Concentration of Oil in Water is dependent on the Mill Requirements.
2. Reduction Gears ---------------------	2150 SSU (464.3 cSt.) Vis @ 100°F., Sul/Phos EP Gear Oil
3. Hydraulic System --------------------	Anti-Wear Hydraulic Oil. Vis dictated by the pump in service
4. Bearings	
Grease Lubricated ----------------	Either of the following:- Lith.12-Hyd.Stearate EP; Aluminum Complex EP; Calcium Complex EP
Mist Oil Lubricated --------------	2150 SSU (464.3 cSt.) Vis @ 100°F. Mist Oil

g. [illegible]

[illegible] Lubrication -------------- Vis. @ 100°F., depending on the application

Note:- It is recommended that [illegible] oils used to lubricate gears, bearings, and other [illegible] parts, have EP characteristics.

SSU	-----	cSt.
[illegible]		[illegible]
315		[illegible]
4[illegible]		10[illegible]
715		15[illegible]
1[illegible]		21[illegible]
1[illegible]		3[illegible]
21[illegible]		4[illegible]

[illegible]

[illegible] Apply [illegible] or brush. — Proprietary Products usually [illegible] the [illegible] type [illegible] materials [illegible] with solvent and [illegible] both [illegible] and [illegible] characteristics.

2. [illegible] Type [illegible] protection [illegible] and [illegible] (hot and/or [illegible] [illegible] mild conditions. Applied [illegible], spray, brush, or [illegible] — Proprietary Products ranging from [illegible], paraffinic base [illegible] oils containing [illegible] additives.

3. [illegible] Oils [illegible] protection [illegible] and [illegible] strip steel [illegible] and/or cold [illegible] during [illegible] and storage. Applied by [illegible], spray, brush, or felt roller. — Proprietary Products affording better [illegible] than that of No.2 [illegible] usually oils containing a [illegible] percentage of polar additives [illegible] non-staining type.

. [illegible]

1. [illegible] Mills ---------------------- Heavy Duty, Petroleum Sulfonate, Soluble [illegible] having a Vis of [illegible] (47.[illegible]-75.5 cSt.) [illegible] in the neat form. [illegible] percentage of oil [illegible] water will depend on the mill conditions

2. [illegible] Mills

[illegible] Plate ---------------------- Naphthenic Base Oil having a Vis of 250-3[illegible] (53.8-75.5 cSt.) [illegible] plus Tallow, Lubricity Agents, biocides, [illegible] certain application requirements, Emulsifiers [illegible]

2. Tandem Mills (Continued)

Tin Plate -------------------------	Blends of Tallow, Stearic Acid and/or other Lubricity Agents and for certain application requirements, Emulsifiers are added.

Note:- For both Black Plate and Tin Plate rolling, the lubricant is applied to the strip by either a Direct Application or a Recirculating System. In the Direct Application System, the lubricant and water are mechanically mixed and the resulting mixture is used only once. In the Recirculating System the lubricant is emulsified with water and the resulting emulsion is used over and over again.

DETAILED OIL, GREASE AND HYDRAULIC FLUID USAGE DATA

BY PLANT AREA AND APPLICATION

Provided by Joseph D. Lykins

AIR, WATER, GAS BI-PRODUCTS, AND POWER EQUIPMENT

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal. or Lb. Per Month
Blowing Engines	Steam Cylinders	Compounded Cylinder Oil, 2150 SSU (464.3 cSt.) @ 100°F., 6-8% Compounding	1600 Gal.
	General Lubrication	300 SSU (64.6 cSt.) Vis @ 100°F., Red Engine Oil	1000 Gal.
Air Turboblowers and Gas Engines	Crank Case and Cylinders	Heavy Duty Detergent Motor Oil SAE 40-50	325 Gal.
	Engine Parts	300 SSU (64.6 cSt.) Vis @ 100°F., Red Engine Oil	350 Gal.
Air Compressors	Crank Case	315 SSU (68.0 cSt.) Vis @ 100°F., R&O Naphthenic Base Oil	500 Gal.
	Cylinders	315 SSU (68.0 cSt.) Vis @ 100°F., Triarylphosphate ester type Oil	250 Gal.
Water Pumps	Gear Drives	700 SSU (151.0 cSt.) Vis @ 100°F., EP Sul/Phos Gear Oil	1600 Lbs.
	Bearings Oil Lubricated	250-700 SSU (53.8-151.0 cSt) Vis @ 100°F., R&O Oil	100 Gal.
	Grease Lubricated	NLGI No. 2, Lith. 12-Hyd. Stearate Grease	400 Lbs.
Steam Turbines Direct Connected	Bearings & Govenor	150-300 SSU (31.9-64.6 cSt) Vis @ 100°F., R&O Oil	600 Gal.
Steam Turbines Geared	Bearings & Gears	300-465 SSU (64.6-100.4 cSt) Vis @ 100°F., R&O Oil	300 Gal.

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal. or Lbs. Per Month
Electric Motors	Bearings Oil Lubricated	150-300 SSU (31.9-64.6 cSt) Vis @ 100°F., R&O Oil	80 Gal.
	Grease Lubricated	NLGI No.2, Lith. 12-Hyd. Stearate Grease	1200 Lbs.
Coke Oven Pushers	Hydraulics	Water-Glycol FR Hydraulic Fluid	675 Gal.
Coke Oven Doors	Door Screws	NLGI No.1, Bentone Grease	800 Lbs.
Coke Oven, General Grease Lubrication	Blast Valves, Plain and Antifriction Bearings	NLGI No.1, Lith. 12-Hdy. Stearate Grease	1200 Lbs.

5 BLAST FURNACES

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal. or Lbs. Per Month
Skip Hoist	Plain & Antifriction Bearings	NLGI No.1, Lith. 12-Hyd. Stearate Grease	600 Lbs.
	Steel Cables	Solvent Cut-Back Gear Shield, or Mfgr's. Recommendation	250 Lbs.
Large & Small Bell Beam Bearings	Plain Bearings and Bell Seals	NLDI No.1, Lith. 12-Hyd. Stearate Grease	200 Lbs.
Reduction Drives	Bevel & Spur Enclosed Gears	1050 SSU (226.7 cSt) Vis @ 100°F., Sul/Phos EP Gear Oil	100 Gal.
	Worm Gear Drives	2150 SSU (464.3 cSt.) Vis @ 100°F., Sul/Phos EP Gear Oil	15 Gal.
General Lubrication Centralized Grease System.	Plain & Antifriction Bearings, Slides, etc.	NLGI No.1, Lith. 12-hyd. Stearate Grease	1400 Lbs.

BOF STEEL FURNACES

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal.or Lbs. Per Month
Trunion Bearings	Antifriction Type	2150 SSU (464.3 cSt.) Vis @ 100°F.,Sul/Phos EP Gear Oil	800 Lbs.
Teco Charging Machines	Hydraulic Systems	300 SSU (64.6 cSt.) Vis @ 100°F., FR Hyd. Fluid, Phosphate Ester Type	300 Gal.
RR Car Journal Bearings	Antifriction Type	NLGI No.2, AAR Approved Grease	1200 Lbs.
General Grease Lubrication	Plain & Antifriction Bearings	NLGI No.1.,Lith. 12-Hyd. Stearate Grease	2000 Lbs.

STEEL MILL AUXILIARIES

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal.or Lbs. Per Month
Air Compressors	Gears & Cylinders	150 SSU (31.9 cSt.) Vis @ 100°F.,R&O Oil	2000 Gal.
Shops	Roll Grinders	Soluble Oil	5000 Gal.
	General Lubrication — Grease	NLGI No.1, Lith. 12-Hyd. Stearate	1600 Lbs.
	Oil — Spindles	150 SSU (31.9 cSt.) Vis @ 100°F.,R&O Oil	300 Gal.
	Oil — Reduction Gear Drives	750 SSU (161.8 cSt.) Vis @ 100°F., Sul/Phos EP Gear Oil	600 Gal.
Cranes	Electric Motor Bearings	NLGI No.2,Premium Ball & Roller Bearing Grease	3000 Lbs.
	Wheel Bearings and General	NLGI No.1, Lith. 12-Hyd. Stearate Grease	6000 Lbs.
	Reduction Gear Drives	1000 SSU (215.8 cSt.) Vis @ 100°F., Sul/Phos EP Gear Oil	950 Gals
		2150 SSU (464.3 cSt.) Vis @ 100°F., Sul/Phos EP Gear Oil	1300 Gal.

44" & 45" BLOOMING MILLS

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal. or Lbs. Per Month.
Mill Approach Tables	Bevel Gears and Plain Bearings	Leaded Residual Type Gear Oil	110,000 Lbs.
Manipulator Drives	Spur, Herringbone, and Worm Gears	2150 SSU (464.3 cSt.) Vis. @ 100 F., Sul/Phos EP Gear Oil or, Lead Naphthnate Type Gear Oil of the same Viscosity	14000 Lbs.
Main Mill Drives	Gears & Antifriction Bearings (Recirculating Oil System)	Same as for Manipulator Drives (Above)	21[illegible]00 Lbs.
Mill Bearings	Babbit Bearings with Bronze Segments	Block Grease (Calcium Soap with Asphaltic Residuum Base Oil	2[illegible],[illegible] Lbs.
Shear Drives	Gears & Antifriction Bearings (Splash Lubricated)	Same as for Manipulator Drives (Above)	[illegible]500 Lbs.
Runout & Cooling Tables	Beveled Gears and Plain Bearings	Leaded Residual Type Gear Oil, 4800 SSU (1036.3 cSt.) Vis. @ 100 F.	110,000 Lbs.
Mill Screw Downs	Steel on Steel, Screw and Nut Centralized Lubricator	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	5000 lbs.
	Worm Drives	2150 SSU (464.3 cSt.) Vis. @ 100 F., Sul/Phos EP Gear Oil	6000 lbs.
Main Drive Motor Bearings	Plain Bearings, Ring Oiled	300 SSU (64.6 cSt.) Vis. @ 100°F., R&O Oil	550 Gal.
General Lubrication, Grease	Plain & Antifriction Bearings	NLGI No.1, Lith. 12-Hyd. Stearate Grease	26,[illegible]00 Lbs.
Slipper Brass	Plain Slipper Brass Bearings	NLGI No.1, Lith. 12-Hyd. Stearate Grease + 5% Moly. Disulfide, and High Molecular Weight Polymers	410 lbs.
Crane & Auxiliary Equipment	Plain & Antifriction Bearings	NLGI No.2, Lith. 12-Hyd. Stearate Grease	1200 lbs.

80" HOT STRIP MILL

Parts & Equipment Lubricated	Type Bearings or Gears	Type of Lubricant Used	Gal. or Lbs. Per Month
Oil Lubrication System "1", Serving Mill Tables between and including Mill Approach Table to Crop Shear	Spur & Bevel Gears	2150 SSU (464.3 cSt.) Vis. @ 100°F., Sul/Phos EP Gear Oil, or Lead Naphthanate Type Gear Oil of the same Vis.	1000 Gal.
Oil Lubrication System "2" Serving Screwdowns, Mill Drives, and Pinion Stands for R1 & R2 Vertical Edgers and Edger Drives E1 & E2	Screw, Spur, Bevel, and Worm Drives	Same as for System "1"	2000 Gal.
Oil Lubrication System "3", Serving Screwdowns, Mill Drives and Pinion Stands for R3, R4, & R5, and Edgers E3, E4, & E5.	Screw, Spur, Bevel, and Worm Gears	Same as for System "1" & "2"	2000 Gal.
Oil Lubrication System "4" Serving Rotary Crop Shear Drives, Finishing Scale Breaker Drives and Six (6) Finishing Mill Drives.	Bevel, Spur, and Herringbone Gear Drives	1500 SSU (323.8 cSt.) Vis. @ 100°F., Sul/Phos EP Gear Oil, or Lead Naphthanate Type Gear Oil of the same Vis.	1500 Gal.
Oil Lubrication System "5", Serving Screwdowns, Pinion Stands F1 thru F7	Bevel Gears, and Screws	Same as for System "4"	1500 Gal.
Oil Lubrication System "6", Serving Stands R1, R2, R3, R4, R5, F1, F2, F3, and F4, and Back-Up Roll Bearings.	Plain Babbit Bearings of the Mesta or Morgoil Type	2100 SSU (453.4 cSt.) Vis. @ 100°F., R&O Oil, or Straight Mineral Oil having good Demulsibility	6000 Gal.
Oil Lubrication System "7" Serving Stands F5, F6, and F7 Back-up Roll Bearings	Plain Babbit Bearings of the Mesta or Morgoil Type	1000 SSU (215.8 cSt.) Vis. @ 100°F., R&O Oil, or Straight Mineral Oil having good Dem.	1500 Gal.
Oil Lubrication System "8" Serving Roughing Train M.G. Synchronous Motor and Main Drive Motor Bearings	Plain Babbit Bearings	315 SSU (68.0 cSt.) Vis. @ 100°F., R&O Oil	100 Gal.
Oil Lubrication System Serving on Finishing Train.	Plain Babbit Bearings	Same as for System "8"	100 Gal.

80" HOT STRIP MILL
(Continued)

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Electric Motor Bearings and Air Compressors (General)	Plain and Spur Gears and Cylinders	150 SSU (31.9 cSt.) Vis. @ 100°F., R&O Oil	660 Gal.
Reheat Furnace Fan Bearings	Plain and Antifriction	100 SSU (20.6 cSt.) Vis. @ 100°F., R&O Oil	100 Gal.
Miscellaneous Brg. Lubrication	Plain and Antifriction	200 SSU (43.0 cSt.) Vis. @ 100°F., R&O Oil	605 Gal.
Oil Mist System	Plain and Antifriction	1000 SSU (215.8 cSt.) Vis.@ 100°F., Mist Oil	200 Gal.
Railroad Switches and Misc. Lubrication of Pig Machines	Plain Brgs. and Drive Chains	1000 SSU (215.8 cSt.) Vis.@ 100°F., Black Oil for Winter, and	150 Gal.
		2500 SSU (539.7 cSt.) Vis.@ 100°F., Black Oil for Summer	300 Gal.
Roll Shop Cleaning Solvent	Bearings and Parts	Stoddard Solvent, Min. Flash - 100°F.	~~160 Gal.~~
Down Coilers, Side Guides, Roll Balance, and Entry Guides	Hydraulic Systems	400/500 SSU (86.2/108.0 cSt.) Vis.@100°F., Inverted Emulsion Hydraulic Fluid	9000 Gal.
Looper Controls and Coil Banders	Hydraulic Systems	Blended Phosphate Ester, FR Hydraulic Fluid	350 Gal.
General Lubrication, Work & Table Roll Bearings, Slides & Ways	Plain and Antifriction	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	35,000 Lbs.
Electric Motor Brgs. and Crain Lubrication	Antifriction	NLGI No.2, Lith. 12-Hyd. Stearate EP Grease	1600 Lbs.
Spindle Brasses and Geared Couplings	-----------	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease plus 3-5% Molybdenum Disulfide, 1% Graphite, and High Molecular Weight Polymers	3500 Lbs.

4 STAND TANDEM COLD MILL

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Back-up Roll Bearings	Mesta, Plain Bearings	1000/2150 SSU (215.8/464.3 cSt.) Vis @ 100°F., R&O Oil, or Straight Mineral Oil having good Demulsibility.	3000 Gal.
Pinion & Reduction Gear Drives	Spur, and Herringbone Gears	1500 SSU (327.8 cSt.) Vis. @ 100°F., Sul/Phos EP Gear Oil	1800 Gal.
Screw Downs	Screw & Worm Gears	6000 SSU (1295.3 cSt.) Vis. @ 100°F., Lead Naphthanate Type EP Gear Oil	1000 Gal.
Piston Pumps, Valves, and Cylinders	Hydraulics	Heavy Duty Soluble Oil (neat)	6000 Gal.
Motors and M.G. Sets	Plain Bearings	150 SSU (31.6 cSt.) Vis. @ 100°F., R&O Oil	500 Gal.
Work Roll Bearings, and General Grease Lubrication	Antifriction and Plain Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	3200 Lbs.
Rolling Oil	---------	50% Fatty Oil 50% Mineral Oil	180,000 Lbs.

COKE OVENS & BLAST FURNACES

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Grease Lubrication (general)	Antifriction and Plain Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	4000 Lbs.
Furnace Linkage	Antifriction and Plain Bearings	NLGI No.1, Bentone Grease	1200 Lbs.
Coke Oven Door Pushers	Hydraulics	200 SSU (43.0 cSt.) Vis. @ 100°F., Water/Glycol FR Hydraulic Fluid	2400 Gal.
Turbo Blowers	Plain Bearings	150 SSU (31.9 cSt.) Vis. @ 100°F., Prem. Quality R&O Oil	300 Gal.

COKE OVENS & BLAST FURNACES
(Continued)

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Auxiliaries	Air Compressors	150 SSU (31.9 cSt.) Phosphate Ester FR Hydraulic Fluid	110 Gal.
	Askania Controls	100 SSU (20.6 cSt.) Vis.@ 100°F., R&O Oil	250 Gal.
	Wash Oil (Coal Bulking Oil)	Waste Oil (Spent Motor Oil, etc.)	1000 Gal.
	Diesel Motor Oil	SAE 40	4 0 Gal.
	RR Car Journal Brgs. Plain	2150 SSU (464.3 cSt.) Vis.@ 100°F., Black Oil	2000 Gal.
	Antifriction	NLGI No.2, Soda/Lime Base Grease	1200 Lbs.

CONTINUOUS PICKLERS

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Reels	Hydraulics	Inverted Emulsion, FR Hydraulic Fluid	3500 Gal.
	Gear Drives	2150 SSU (464.3 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	1000 Gal.
	General Grease Lubrication	NLGI No.1, Lith. 12-Hyd. Stearate EP grease	2400 Lbs.
Coil Coating Oils	Rust Protective Oils (Hot Band Shipments)	100 SSU (20.6 cSt.) Vis.@ 100 F., Proprietary Products	1500 Gal.
	Rolling Oils	Fully Fatty Oils	9 ,000 Lbs.
General Grease Lubrication	Antifriction and Plain Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	400 Lbs.

5 STAND TANDEM COLD MILL

Tin Plate Product

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month
Coil Cars, Coil Lifts, Turnarounds, Upenders, Roll Ballance, & Jacks.	Hydraulics	Inverted Emulsion FR hydraulic Fluid	3,000 Gal.
Back-up Roll Bearings	Mesta Plain Brgs. Stands:- No. 1, 2, & 3	2150 SSU (464.3 cSt.) Vis.@ 100°F., R&O Oil having good Demulsibility	2,500 Gal.
	No. 4 & 5	1000 SSU (215.8 cSt.) Vis.@ 100°F., R&O Oil having good Demulsibility.	1,500 Gal.
Reduction Gear Drives	Stands:- No. 1, 2, & 3	2150 SSU (464.3 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	800 Gal.
	No. 4, & 5	1000 SSU (215.8 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	600 Gal.
Couplings	Geared	NLGI No. 1, Lith. 12-Hyd. Stearate EP Grease plus 3-5% Molybdenum Disulfide, 1[illegible] Graphite, and High Molecular Weight Polymers	1,200 Lbs.
Motors and MG Sets	Plain Bearings	150 SSU (31.9 cSt.) Vis.@ 100°F., R&O Oil	150 Gal.
		300 SSU (64.6 cSt.) Vis.@ 100°F., R&O oil	200 Gal.
	Antifriction Bearings	NLGI No. 2, Lith. 12-Hyd. Stearate EP Grease	450 Lbs.
Rolling Oil	-- --------	90% Tallow, 5% Stearic Acid, 5% Oxidation Inhibitors, Emulsifiers, etc.	560,000 Lbs.

[illegible]LYTIC [illegible]

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or Lbs. Per Month.
Reels	Hydraulics	300 SSU (64.6 cSt.) Vis.@ 100 F., Anti-Wear Hydraulic Oil	5[illegible]0 Gal.
Reduction Gear Drives	Spur, Worm, Helical Gears and Ways	2100 SSU (453.4 cSt.) Vis.@ 100 F., Sul/Phos EP Gear Oil	2[illegible]00 Lbs.
Electric Motors	Ball & Roller Bearings	NLGI No.2, Lith. 12-Hyd. Stearate EP Grease	75 Lbs.
General Grease Lubrication	Antifriction and Plain Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	700 Lbs.

ELECTROLYTIC TIN LINES

Coilers, Shears, and Welders	Hydraulics	300 SSU (64.6 cSt.) Vis.@ 100°F., Anti-Wear R&O, Hydraulic Oil	5[illegible]0 Gal.
Slides, Guides, and Reel Collapsing Mechanism	Antifriction and Plain Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	22[illegible]0 Lbs.
	Internal Gears	1500 SSU (323.8 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	2700 Lbs.
Pinch & Bridle Rolls	Internal Gears	1500 SSU (323.8 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	[illegible]500 Lbs.
Pickling Tank:- Overhead Conductor and Bottom Looper Rolls	Antifriction Bearings	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	50 Lbs.
Plating Tank:- Scrubber Rolls, Overhead Rubber and Looper Rolls	Antifriction Bearings	700 SSU (151.0 cSt.) Vis.@ 100°F., EP Mist Oil	50 Gal.

ELECTROLYTIC TIN LINES

(Continued)

Parts & Equipment Lubricated	Type Bearings or Gears	Type Lubricant Used	Gal. or I Per Mont
Roller Leveler and Flying Shears	Internal Gears, Chains, Roll Adjustment Screws, and Universal Drives	1000 SSU (215.8 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	2200 lbs
	Worm Gears	2150 SSU (464.3 cSt.) Vis.@ 100 F., Sul/Phos Gear Oil	50 Gal
	P.I.V. Unit Drives	700 SSU (151.0 cSt.) Vis.@ 100°F., Sul/Phos EP Gear Oil	100 Gal
	General Grease Lubrication	NLGI No.1, Lith. 12-Hyd. Stearate EP Grease	120 lbs.

JJL:ICM

MONTHLY LUBRICANT USAGE DATA SUMMARY

(Prepared by PES based on preceeding Lykins' tabulation)

Air, Water Gas By-Products and Power Equipment	
lubricating oils*	4,105 gal
	1,600 lb
greases	3,600 lb
hydraulic fluids	675 gal
Blast Furnaces	
lubricating oils	115 gal
greases	2,450 lb
hydraulic fluids	0 gal
BOF Steel Furnaces	
lubricating oils*	0 gal
	800 lb
greases	3,200 lb
hydraulic fluids	300 gal
Steel Mill Auxiliaries	
lubricating oils	5,150 gal
greases	10,600 lb
hydraulic fluids	0 gal
process oils (soluble oil roll grinders)	5,000 gal
Coke Ovens & Blast Furnaces	
lubricating oils	2,950 gal
greases	6,400 lb
hydraulic fluids	2,570 gal

[Subtotal For Above Departments]

lubricating oils*	12,320 gal
	2,400 lb
greases	26,250 lb
hydraulic fluids	3,545 gal
process oils	5,000 gal

44' & 45" Blooming Mills

lubricating oils*	550 gal
	269,500 lb
greases	62,610 lb
hydraulic fluids	0 gal

80" Hot Strip Mill

lubricating oils	17,715 gal
greases	40,100 lb
hydraulic fluids	9,350 gal

4 Stand Tandem Cold Sheet Mill

lubricating oils	6,900 gal
greases	3,200 lb
hydraulic fluids	6,000 gal
rolling oils	180,000 lb

Continuous Picklers

lubricating oils	1,000 gal
greases	2,800 lb
hydraulic fluids	3,500 gal
rolling oils	90,000 lb
rust preventatives	1,500 gal

<u>5 Stand Tandem Cold Tin Mill</u>	
lubricating oils	5,750 gal
greases	1,650 lb
hydraulic fluids	3,000 gal
rolling oils	560,000 lb
<u>Electrolytic Washers</u>	
lubricating oils*	0 gal
	2,000 lb
greases	775 lb
hydraulic fluids	500 gal
<u>Electrolytic Tin Lines</u>	
lubricating oils*	200 gal
	7,400 lb
greases	3,450 lb
hydraulic fluids	500 gal
[<u>Sub Total for Rolling & Finishing Operations</u>]	
lubricating oils*	32,115 gal
	278,900 lb
greases	114,585 lb
hydraulic fluids	22,850 gal
rolling oils	830,000 lb
rust preventatives	1,500 gal

TOTAL USAGE

lubricating oils*	44,435 gal
	281,300 lb
greases	140,835 lb
hydraulic fluids	26,395 gal
rolling oils	830,000 lb
process oils	6,500 gal

77,330 gal x 7.5 lb/gal =	579,975 lb
	1,252,135 lb
Total	1,832,110 lb/month

* Note: gear oil quantities are reported in both gallon and pound units.

APPENDIX D

Waste Oil Collection, Reclamation and Disposal in the Steel Industry

Provided by
Richard Jablin

WASTE OIL COLLECTION, RECLAMATION AND DISPOSAL IN THE STEEL INDUSTRY

LIST OF TABLES, GRAPHS & FIGURES

I - Types of Steel Mill Oily Wastes

The typical integrated steel mill uses a large variety of hydraulic, lubrication and rolling oils as well as greases. These are used in the following general classifications:

- Hydraulic oil for shearing, and coil handling equipment
- Lubrication of rolling mill gears, bearings, etc.
- Rolling oil for cooling and lubricating strip during cold rolling
- Crankcase oil for mobile equipment and railroad equipment
- Rust preventative oiling of finished products
- Miscellaneous lubrication and hydraulic applications in the primary areas, i.e., iron and steelmaking

The oily wastes generated fall into four broad categories:

- Water discharges containing relatively small amounts of oil (~100 ppm), mill contact cooling water

- Soluble oil - water solutions, primarily from cold rolling (~2-6% oil)

- Contaminated or used oil, being essentially 100% oil

- Solid wastes contaminated with oil and greases, including roll scale, oil clean-up, debris, etc.

To make any meaningful assessment, the individual processes must be considered separately because the types of lubricants and quantities used vary widely between processes. In this report we will consider the following processes:

- Primary, Slabbing and Structural Mills

- Continuous Casters

- Plate Mills

- Hot Strip Mills

- Tandem Mills

- Pickling Lines

- Temper Mills

- Tin Plate Mills

- Galvanizing Lines

- Terne Coating Lines

- Coke Ovens

- Blast Furnace

- Basic Oxygen Steelmaking

HOT FORMING OPERATIONS

Wastewater result from the hot forming operation because of the large amount of direct contact cooling and descaling waters required between the hot steel and the rolling mill equipment. Approximately 4% of the water sprayed on the steel evaporat : and the balance is discharged beneath the rolling mill equipment to trenches called flumes.

When the hot steel product is being rolled, iron oxide scale keeps forming on the surface of the hot steel and this scale is continuously removed by direct contact high pressure (1,000 - 2,000 psig) spray water before each roll pass of the product. Low pressure spray cooling water is also used to keep the mill stand and table rolls cool as the hot steel passes over or in between them.

The wastewaters from descaling and mill equipment cooling are generally discharged via flumes or trenches to inground concrete settling chambers called scale pits where the heavier iron oxide particles are settled out. These scale pits generally contain underflow weirs with launders to trap oils and greases picked up by the cooling waters. The waste oils are removed from the water surfaces by belt, rope, or other type of floating oil skimmers, and pumped to large capacity waste oil storage tanks where contract haulers periodically remove the accumulated oils. The scale is cleaned out by mechanical means such as clam shell buckets, drag link conveyors, etc.

The wastewaters discharged from scale pits are either discharged to plant sewers or are recycled back to the mills. The suspended solids content in overflows is generally 100 to 200 mg/L, but these wastewaters can be further treated by means of filtration or thickeners with chemical coagulation.

Due to the many different types of hydraulic and lubrication systems required to maintain the rolling mill equipment, the direct contact cooling and descaling waters pick up oil and greases when being sprayed over the mill equipment. Also, water soluble oil solutions are sometimes used for mill roll spray coolant waters.

HOT FORMING - PRIMARY

Blooming and Slabbing Mills

The blooming and slabbing mills have generally four main plant water systems.

a. Descaling water sprays
b. Table roll cooling sprays
c. Scarfer water spray system
d. Mill stand cooling sprays

All the water cooling and descaling systems are generally a once-through water system discharged into a scale pit where the scale is settled out, oil is trapped by means of weirs and the overflow water is pumped to a sewer. Some mills do not have scale pits but use mechanical means such as drag scrapers or clam buckets for the scale removal while the water is collected in a sump and pumped to a central plant water treatment system.

HOT FORMING - SECTION

Section mills generally have water systems similar to primary mills as discussed above. The wastewaters produced are primarily the result of reheat furnace non-contact cooling waters, mill equipment cooling waters, and high pressure spray water descaling systems. The furnace cooling waters are generally once-through and discharged to plant sewers.

The mill equipment cooling and high pressure descaling waters are discharged via flumes and trenches to scale pits where the heavier solids are settled out. Oils and greases picked up by the cooling waters are trapped in the scale pits by means of underflow weirs and launders.

The oils are removed from the surface of scale pit waters by means of belt, rope or floating type oil skimmers, and pumped to large capacity oil storage tanks where contract haulers periodically remove the accumulated oils. The scale pit overflow waters are generally discharged to plant sewers, but sometimes recycled back to the mills as sluicing or flushing waters in flumes and trenches. Some mills use mechanical scraper or drag line buckets to remove the heavier iron oxide scale beneath the the mill stands and stock pile the scale for recycling in mills. The waters are still flushed into scale pits or settling chambers for final sedimentation and skimming of waste oils and grease.

PLATE MILLS

The plate mills have generally four types of mill water systems:

a. Descaling water sprays - Direct Contact
b. Table roll and plate cooling water sprays - Direct Contact
c. Mill stand roll cooling sprays - Direct Contact
d. Reheat slab furnace skid cooling water - Non-Contact

The slab reheat furnace non-contact cooling waters can either be once-through or recycled water systems depending upon mill water availability. Flows up to 315 l/sec (5,000 gpm) are required to cool the furnace skids but discharged waters are non-contact cooling and will only pick up heat. The descaling sprays, table roll, and plate cooling sprays and mill stand rolling cooling sprays are generally once-through systems where the waters are discharged to flumes or sumps beneath the plate mill stands. The scale and oil-bearing waters are flushed into scale pits where the majority (up to 90%) of scale is settled out, oil is removed by means of weirs and skimmers and scale pit overflow water is discharged to sewers. Removal of scale is generally through mechanical means such as cranes with clam buckets or drag scraper conveyors beneath the mill stands.

HOT STRIP MILLS

The hot strip mills have generally five types of mill water systems:

a. Slab reheat furnace cooling water - Non-Contact
b. High pressure descaling water - Direct Contact
c. Low pressure roll coolant water - Direct Contact
d. Table roll and shear cooling waters - Direct Contact
e. Strip spray cooling waters - Direct Contact

The slab reheat furnace non-contact cooling waters descaling sprays, shearing cooling, scale and oil-bearing waters are as described above for plate mills.

The strip spray cooling waters are sprayed to cool the strip after it has been rolled on the final mill finishing stands. This water system may be once-through if good quality water is available, but because of the great quantities required, (up to 4,400 l/sec (70,000 gpm) on new hot strip mills) recycle systems are installed. Approximately 8% of the strip cooling waters evaporate and the balance is either discharged to sewers or recycled. The suspended solids in overflow waters is generally 100 to 200 mg/L.

PIPE AND TUBE MILLS

Pipe and tube mills can be classed into three types of hot forming production methods: Butt welded pipe; Electric-resistance welded tubing, and Seamless tubes.

The butt welded pipe mills generally have three types of water systems.

1. Non-contact cooling waters in skelp heating furnaces - water cooled skids, water cooled welding bell, etc.

2. Roll cooling spray waters.

3. Pipe cooling bed water bosh.

The skelp heating furnace non-contact cooling waters can either be once-through or recycled water systems depending upon mill water availability. The effluent waters are non-contact cooling waters and will only increase in heat content.

The roll cooling spray waters are generally once-through water systems where the scale and oil-bearing waters are discharged to flumes or trenches beneath the pipe mill roll stands and in turn flushed into scale pits where scale is settled out and oils removed by means of weirs and skimmers. Removal of scale is generally through mechanical means such as drag scraper conveyors, clam buckets hung on overhead cranes, etc. About 4% of the spray waters evaporate and the balance is discharged to the scale pits.

The pipe cooling bed water bosh is sometimes used to provide adequate cooling capacity without excessively long pipe cooling beds. The waters are generally once-through systems providing direct control cooling and waters are discharged into the roll cooling water systems.

PIPE AND TUBE MILLS (continued)

The electric-resistance welded tubing mills have only two types of water systems.

1. Non-contact cooling water for equipment welders, etc.
2. Water soluble oil spray cooling systems.

Electric-resistance welded tubing is formed by cold rolling and then is heated by the electric welder as the tube seam is welded. The tube is cooled by passing through a spray of water soluble oils. These waters are generally recycle systems and make-up is required.

The seamless tube mills generally have three types of water systems:

1. Non-contact cooling waters - reheat furnaces, water cooled, piercing mandrels, etc.

2. Roll spray coolant waters

3. Spray water quench

The non-contact cooling waters for furnaces or piercing (tube shaping) mandrels can either be once-through or recycled depending upon mill water availability. The non-contact effluent waters will only increase in temperature.

The roll spray coolant waters are generally once-through systems where the spray water is discharged to scale pits via flumes and trenches beneath the tube mill stands. Scale is settled out and oil is trapped and removed by means of weirs and skimmers.

The spray quench water system is used to produce higher strength tubes than just hot working the tubing. The tubing is quenched, reheated, and quenched by means of water sprays. These waters are once-through systems.

PICKLING

The primary function of a pickling facility is to chemically remove iron scale from steel. The amount of iron removed depends upon the type of steel being pickled and the specific condition of the product. As an example, heavy and bulky steel shapes, such as billets, bars, etc., may experience an iron weight loss (due to pickling) of 1/4%. This would amount to 5 lb Fe loss per ton being pickled. Steel strip or sheet is more typically 1/2% (10 lb Fe per ton pickled). Rod (for manufacture of wire) ranges from 1/2% to 2% (10 lb to 40 lb per ton). The three major wastewater sources associated with pickling are inseparable from the process. They include:

Spent Pickle Liquor. The pickling solution becomes progressively saturated with ferrous salts. When the ferrous salt content reaches a certain level, the acid becomes ineffective and has to be dumped.

PICKLING (continued)

Rinse Water. Rinse water is pickle liquor in dilute form. Disposal of large quantities of rinse water poses a difficult and serious problem.

Acid Vapors and Mists. The emission of pungent and corrosive mist and vapor from the pickling tanks presents serious hazards, both indoors from a health and maintenance standpoint and outdoors as air pollution.

In addition to the free acid and ferrous salt content, the spent liquor could also contain relatively small amounts of other metal sulfates, chlorides, lubricants, in hibitors, hydrocarbons, and other impurities.

RINSE WATERS

After pickling is achieved in the acid bath, the material is subjected to a water rinse to remove the acid/iron solution prior to further processing. The traditional method of rinsing calls for high volumes of fresh water simply to wash the pickled product by flushing. Pickling facilities vary; however, typical rinse water volumes range from 1.5 to 65 l/sec (25 to 1,000 gal/minute) flow rate. The larger continuous strip pickling lines use 6 to 65 l/sec (100 to 1,000 gpm), most often closer to 20-25 l/sec (300-400 gpm). Batch type pickling facilities average about 1.5 - 20 l/sec (25 to 300 gpm).

COLD ROLLING OPERATIONS

The major water use on cold reduction mills is for cooling the rolls and the material being rolled. This is accomplished by using a flooded lubrication system to supply both lubrication and cooling. A water-oil emulsion is sprayed directly on the material and rolls as the material enters the rolls. Each stand has its own sprays and where recycle is used, its own recycle system. Past practice has been the direct sewering of the emulsion. However, the high cost of rolling oils and the expense of complying with pollution control regulations are modifying this practice, and recycle and recovery systems are currently in common use.

The water used in a cold rolling mill must be a fairly good quality water, free of suspended matter. High quality rolling oils are added to form the emulsion. Since the material being rolled is clean and free from rust, and since no scale is generated during the rolling, oil and temperature are the basic pollutants in this discharge.

Those mills still using once-through solution systems have installed oil recovery plants. The recovered oil is returned for processing or otherwise disposed of. Those mills operating recirculation systems on all mill stands have no continuous discharge of wastewaters. However, means must be provided for the treatment or disposal of batch discharges of spent rolling solutions. The majority of plants operate as combinations of bath systems, and will have significant volumes of continuously running wastewaters.

COLD ROLLING OPERATIONS (continued)

Regardless of what systems are used, miscellaneous oil leaks and spills can occur. One area associated with the cold rolling operation but separate from the rolling mill itself is the maintenance and roll finishing shop. Oil-bearing wastewater originating in these areas is a major contributor to wastewater discharges from a cold rolling mill using total recirculation on all stands. Oil and water leaks in the oil basement also contribute heavily to this problem.

Considerable heat is generated during heavy reductions at high speed on the various types of mills. Not only is the temperature of the product raised but also the temperature of the rolls. This heat is removed from the mill via a flooded lubrication system. A water-oil emulsion is sprayed on the material as it enters the rolls. This emulsion drains off between stands and each stand has its own spray system. In the older mills this emulsion was used once and sewered without any treatment.

Modern continuous cold reduction mills recycle the oil emulsion in the flooded lubrication system. Each stand has its own collection tank and pump to return the emulsion to the sprays. A five stand tandem mill would have five recycle systems, one for each stand. With this arrangement, it is possible to renew one tank of emulsion at a time, or all at once. It is also possible to use different oil emulsions in each tank if the product being rolled so requires. Mills using these recycle systems have no direct discharge to the sewer. However, they do have the problem of disposal of large batch dumps of spent rolling emulsions.

Mills using once-through systems usually install treatment plants and palm oil recovery systems to reclaim these oils for reprocessing and reuse. In this process various techniques are used to break the emulsion to separate the oil from the water. The water is discharged while the oil is returned to a processor for upgrading and resale. The cost of palm oil and the treatment cost for its recovery brought about the development of the recycle system.

The high cost of rolling oil has discouraged mills from using the once-through system, hence it is the oil cost and not pollution control that dictates the type of system to be installed in mills. The recycle system eliminates the continuous discharge of oil emulsions from cold rolling mills.

HOT COATING OPERATIONS

Wastewaters generated by the various hot coating techniques practiced in the iron and steel industry fall into three categories:

1. Continuously running rinse waters, which may include rinses following alkaline and acid cleaning operations; rinses following chemical treatment and surface passivation operations; final rinses; and running wastewater flows from fume scrubbing systems associated with air pollution control devices.

HOT COATING OPERATIONS (continued)

2. Intermittent discharges, which may include spent baths from alkaline and acid cleaning operations; flux baths; chemical treatment solutions; and ion exchange regenerant wastewater, being either recovered or regenerated as part of the coating operations, or sold to outside contractors for processing and recovery.

3. Non-contact cooling waters associated with the hot coating processes may include furnace cooling water and molten metal pot cooling water.

Galvanizing

The continuously running rinse waters generated in galvanizing may include alkaline cleaning rinses; sulfuric or hydrochloric acid rinses; and chromate or phosphate treatment final rinses. Combined total flow rates may range from 10 to 150 l/sec (158-2,380 gpm), depending upon whether the non-contact cooling waters are included or not. The wastewaters may contain suspended and dissolved matter, sulfates, chlorides, phosphates, silicates, zinc, chromium, and oily matter in concentrations rainging from traces to high levels, depending on galvanizing line operating conditions. Intermittent overflows of concentrated alkaline or acid cleaning solutions and flux tank solutions may occur, contributing to the load normally running continuously. These can be minimized by close attention to maintenance and operating conditions and through provision of dragout recovery units where possible. Spent pickle liquor is normally collected separately for disposal or treatment. Typical non-contact cooling water sources from galvanizing lines include zinc pot cooling and, from the so-called "furnace lines," indirect furnace cooling waters.

Terne Coating

The continuously running rinses from the terne coating operation may include rinses following immersion in alkaline or mineral spirit degreasing solutions; and sulfuric or hydrochloric acid rinses. Total flows may range from 10 to 60 l/sec (158-950 gpm depending upon whether the non-contact cooling waters are included or not. This wastewater may contain suspended and dissolved matter, oily matter, sulfates, chlorides, iron, lead, and tin in concentrations which depend on line operating conditions. Intermittent discharges are limited to dragout or spills from cleaning and pickling tanks. Spent pickle liquors are normally collected separately for disposal or treatment. The non-contact cooling water originates due to the necessity for continuously cooling the molten terne pot.

II - The Waste Oil and Wastewater Treatment Problem

The incentive for control of waste oil is two-fold. All steel mills are subject to some limitation on oil and greases (more properly hexane extractables) permitted in discharged wastewater. This is typically 10-15 mg/L. Although the EPA Effluent Guidelines provide total weight limitations in terms of kg/kkg production, in most cases it will be found that the concentration limitation is more restrictive. A second major incentive is control of lubrication costs. Typical general duty mill grease costs about 20¢/pound and rolling and hydraulic oils about 70¢/gallon. The recovery of these materials can be a significant cost-saving. At this point in time, most mills find it economical to recover oil for combustion use rather than actual reclamation for reuse as a lubricant. One exception to this is the routine filtering and centrifuging in some cases of cold mill soluble rolling oil. This is done routinely using systems integral to the mill.

Despite the incentive, oil control is still a major problem for many mills, especially older mills with sewer systems installed prior to the awareness of water pollution control. The use of oils and greases is so pervasive that control requires a comprehensive effort of both equipment and operating practices.

Before proceeding, it is well to review briefly the environmental impact of oil and grease discharges in general.(1)

Concentrations of oil and grease which adversely affect aquatic organisms are difficult to determine because of the numerous compounds comprising oil and grease. For example, the major components of crude oil can be categorized as aliphatic normal hydrocarbons, cyclic paraffin hydrocarbons, aromatic hydrocarbons, naptheno-aromatic hydrocarbons, resins, asphaltenes, heteroatomic compounds, and metallic compounds.(2) The aromatic hydrocarbons appear to be the major acutely toxic group of compounds. In a review of toxicity tests for oily substances the National Academy of Science (3) concluded that tests conducted provide a broad range of results which does not permit rigorous evaluation. Reasons for the variability result from differences in petroleum products tested, non-uniform testing procedures, and species differences. Much of the research has been done with pure compounds which exist only in low percentages in many petroleum products and crude oils. With these limitations in mind a brief review is given of toxic concentrations of oil and grease.

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(1) These comments are abstracted from "Evaluation of the Effects of the Iron and Steel Phase II Effluent Guidelines on Energy Use in the Hot Forming Sub-Categories".

(2) Bestougeff, M.A., "Petroleum Hydrocarbons," in Fundamental Aspects of Petroleum Geochemistry, B. Nogy and U. Colombo, eds. Elseuier Publishing Company, New York, New York, 1967, pp. 109-175.

(3) Environmental Studies Board, National Academy of Sciences, National Academy of Engineering, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Washington, D.C., 1972, EPA.Re.73.033, March 1973.

II - The Waste Oil and Wastewater Treatment Problem (continued)

Free oil and emulsions may adhere to gills of fish causing asphyxiation and coat aquatic plants.[3] Oils may also become sedimented resulting in adverse effects on bottom dwelling organisms. Also, organisms may ingest oils resulting in bioaccumulation.

Bioaccumulation of petroleum products presents two important public health problems:[4] tainting of edible, aquatic species and the possibility of edible organisms incorporating the high boiling, carcinogenic polycyclic aromatics in their tissues. Crude oil at concentrations of 0.01 mg/L has caused oil taining in oysters.[5] Marine organisms have been shown to incorporate potentially carcinogenic compounds into their body fat where the compounds remain unchanged.[6, 7]

Oil pollutants incorporated in sediments may remain toxic for long periods. This occurs when oils become incorporated below the aerobic surface layer where bacterial degradation is slow.[3] No.2 fuel oil incorporated into marine sediments persisted for over a year and began spreading in the form of oil-laden sediments to more distant areas.[6, 7]

Variations in toxicity with various petroleum products can be illustrated by results of bioassay test on the american shad (alosa sapidissima). Concentrations which resulted in 50 percent mortality of the test fish within a 48-hour period (48-hour LC_{50}) were 91 ppm gasoline 167 ppm diesel fuel and 2417 ppm bunker oil.[8] An example of a sublethal concentration is a kerosene concentration of 0.001 to 0.004 mg/L which caused a reduction in the chemotactic perception of food by the snail, Nassarius obsoletus.[9]

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(3) Environmental Studies Board, National Academy of Sciences, National Academy of Engineering, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Washington, D.C., 1972, EPA.Re.73.033, March 1973

(4) Quality Criteria for Water, U.S. Environmental Protection Agency, Draft Report, 1976.

(5) Smith, N.A., Oil Pollution and Marine Ecology, Plenum Press, New York, 260 p.

(6) Blummer, J., "Oil Contamination and the Living Resources of the Sea, No. R-1 in Report of the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, FAO Fisheries Report 99.

(7) Tagatz, M.E., "Reduced Oxygen Tolerance and Toxicity of Petroleum Products to Juvenile American Shad." Chesapeake Science, Vol. 2, No. 12, 1961, pp. 65-71.

(8) Jacobson, S.M. and Boylan, G.B., "Effect of Seawater Soluble Fraction of Kerosene on Chemotaxis in a Marine Snale, Nassarius obsoletus, "Nature, Vol. 241, 1973, p. 213.

II. The Waste Oil and Wastewater Treatment Problem (continued)

The brief review of effects of petroleum products on aquatic life illustrates the difficulty of establishing a criteria for oil and grease. However, in a recent draft of criteria a concentration of not more than 0.01 ppm was recommended as an upper allowable level for petroleum products in general.(4) A discussion of this criteria within the draft document recognized that sub-lethal effects may occur at lower concentrations of some products and that levels higher than 0.01 mg/L may have no toxic effects in other instances. Since not all oils can be emulsified the use of any general criteria expressed in terms of concentration is questionable.

We shall not consider in this report any air pollution impact of either volatilization of oil and greases or the combustion of oil after recovery. There are air pollution effects but they are considered insignificant relative to fuel oil combustion in a steel mill. Several reports (53,54) discuss the evolution of hydrocarbons from sintering mill scale. Table I shows an analysis of tramp oil (primarily soluble rolling oil) recovered by chemical cracking using demulsifiers and heating. Although various metals are present, this oil is mixed with regular fuel oil and diluted to an insignificant percentage.

The method to measure "oil and grease" is very non-specific since no solvent is available that will selectively extract only "oil and grease" from a wastewater sample. Thus, the solvent can extract other components present in a sample which will then be measured as "oil and grease." Some organics present in water may be formed through natural processes such as the decomposition of plankton or other forms of aquatic life. These will also be measured as "oil and grease." After standing, solvents can form oxidation products which leave a gummy residue on evaporation. This residue will then be measured as "oil and grease". Also, emulsions can form on extraction which contribute to erroneous results.

In carrying out this analytical procedure, the solvent is removed by evaporation after extraction to leave a residue, which is then weighed. However, it is extremely difficult to accurately determine the point when all of the solvent has been removed and only extracted material remains. This can be a serious source of error and can vary considerably with the analyst carrying out this procedure.

Precision data are not reported for this method. However, the precision and accuracy must be poor because of the serious limitations of this procedure noted above. If the quantity of oil or grease is extremely small, the technical skill of the analyst may be the most important factor in the accuracy of the analysis. This implies that values obtained by two analysts on the same sample can be significantly different.

Also, it is difficult to obtain a representative sample for analysis, since "oil or grease" can be present in water as an emulsion, as floating substance (film) and in solution in the water. It is impossible to evaluate an oil film on the surface of an effluent stream in relation to the volume of water, or to measure its total film area and thickness.

II. The Waste Oil and Wastewater Treatment Problem (continued)

The control of waste oil and wastewater can be considered from four separate standpoints:

- Control of usage including leak control
- Recovery of oil directly through skimming, draining, etc.
- Wastewater capture and treatment
- Changes in equipment design and lubrication science to minimize usage and contamination of water

Hydraulic oil leaks can be a surprisingly large percentage of total consumption. The oil which leaks will represent an increased load to the water treatment plant and may or may not impair water quality depending on the capacity and efficacy of the treatment system. Leakage will also result in higher discharges in clean-up residue and may result in direct ground contamination or direct discharge to waterways where it finds its way into non-contact cooling water sewers which do not go through water treatment.

The report included as Appendix A gives an indication of the complexity of the leak potential in a small cold rolling complex (150,000 NT/year). The program described in this report reduced hydraulic oil consumption from 32,000 gal/month to 15,000 gal/month.

This is an extreme case where equipment had been allowed to deteriorate and operating practice was indifferent. Reports from other mills, however, show that some degree of leakage is inevitable. A well maintained cold mill would appear to have a minimum leak rate of 2%. A typical leak rate for a cold mill is considered to be 10%. Table II excerpted from reference 37 provides further insight on the impact of leaks.

The recovery of oil by skimming or draining equipment is the first line of recovery and among the simplest of technologies. This is limited to insoluble floating oils, i.e., hydraulic oils and motor oils. Skimming is accomplished at various locations in the process stream. It can be done at recovery sumps directly under the rolling mills, at scale pits serving hot rolling mills, at quiescent basins preceding clarification, on the surface of clarifiers or lagoons serving as primary or secondary treatment. The equipment used is described in Chapter III.

Direct recovery or draining is, of course, limited to oils contained in holding chambers of various sorts, the typical case being crankcase oils and reservoir oils for compressors. Very high (85%) recovery rates are possible in this case, but poor or sloppy practice could result in direct ground drainage or sewer drainage.

Wastewaters contaminated with small amounts (100 mg/L) of oil and grease are difficult to treat if primary skimming and isolation of oil-water rolling emulsions are not done beforehand. Many typical treatment systems are described in the bibliography and summarized in Chapter III.

TABLE I

* Analysis of Tramp Oil Recovered By Cracking

BTU	-	19,000 BTU/lb
API Gravity	-	21.4
Density	-	7.7 lb/gal
Si	-	88 ppm
Fe	-	700 ppm
Pb	-	36 ppm
Al	-	55 ppm
Cu	-	30 ppm
Mn	-	4 ppm
Mg	-	1 ppm
Ni	-	6 ppm
Ca	-	10 ppm
Na	-	2 ppm
S	-	.25%

* Average of four samples

TABLE II

LOSSES BY OIL LEAKS

LEAKAGE	LOSS IN 1 DAY Gallons	LOSS IN 1 DAY Value** Dollars	LOSS IN 1 MONTH Barrels***	LOSS IN 1 MONTH Value** Dollars	LOSS IN 1 YEAR Barrels***	LOSS IN 1 YEAR Value* Dollars
One drop* in 10 sec	0.112	0.05	0.06	1.65	0.72	19.80
One drop* in 5 sec	0.225	0.10	0.12	3.90	1.44	39.60
One drop* per sec	1-1/8	0.55	0.62	16.90	7.44	204.60
Three drops* per sec	3-3/4	1.85	2.05	56.40	22.60	621.50
Stream breaks into drops	24	12.20	13.1	360.25	157.2	4323.00

*Drops approximately 11/64 in. dia.
**Based on 50¢ per gal
***Based on 55 gal bbl

One drop in 10 sec = 200% makeup per year
One drop in 5 sec = 400% makeup per year
One drop in 100 sec = 20% makeup per year

II - The Waste Oil and Wastewater Treatment Problem (continued)

A final area of consideration is the reduction in oil and grease usage. Leak control has already been discussed but other opportunities exist. It seems unlikely that significant reduction will be made in the near future but the following references in the bibliography suggest interesting approaches to minimizing oil and grease usage and concommitant water contamination: (6) (9) (17) (19) (21) (22) (27) (30) (44) (45) (48).

Consumption of oils and greases varies greatly by steel mill. Using approximate data only, the grease usage varies from .28 to 1.86 lbs/ingot ton. Total oil usage varies from .11 to 1.11 gal/ingot ton. Those mills producing heavy product will generally have higher grease and lower oil consumption and mills producing light product will have higher oil consumption.

In Chapter V we will examine the fate of these quantities in detail.

III - Waste Oil Collection and Wastewater Treatment Equipment

It is difficult to summarize briefly the many variations in specific treatment systems, and for this reason, we have attached an extensive bibliography on the subject. In general, however, there are seven major types of systems:

1. Recirculation and filtering of cold mill soluble oil at mill.

2. Scale pit skimming following by clarification and secondary skimming.

3. Clarification can be supplanted or supplemented by deep bed filtering.

4. Soluble oil cracking systems employing chemical treatment and heating.

5. Centralized collection of wastewaters with lagooning either by itself or after clarification.

6. Centralized tramp oil reclamation.

7. Plant-wide collection of waste oils separate from water systems.

IV - Waste Oil Reclamation, Reuse & Disposal

The recovery of waste oils comprises basically three methods:

1 - Skimming of floating oils from wastewater followed by a gravity or chemical separation procedure dependent on the purity of skimming.

2 - Direct recovery of oils from mill sumps, compressors, fans, crank-cases, etc.

3 - Chemical cracking of soluble oil-water emulsions

The recovery systems in any given mill may be separate or combined in a terminal treatment plant. Several of the references provided in the bibliography discuss a variety of recovery schemes.

Review of the literature indicates that the bulk of recovered oil is used as fuel and not reclaimed for reuse as a lubricant or hydraulic fluid. The reason for this is that in most systems, there is contamination of various oils and separation into specific fractions is not economically feasible. Furthermore, many of the waste oils will have lost their original properties through oxidation and contamination. On-site recirculating systems installed integral to cold rolling mills and palm oil recovery plants are a notable exception to this.

V - Discharge Rates, The Material Balance

Table III shows a comparison of various sources for oil consumption per ton of product for various sub-categories. There are some high discrepancies revealed between these values. Even estimates by EPA vary widely in what is essentially the same report, i.e., the BPT background document. Column 1 and 5 should equal column 2 but in some cases are way off. This discrepancy is not understood but is probably due to flow rate data variations.

Available data from reporting mills has been used to get an indication of which of the values in the table are correct. The values from column 5 have been used in the calculation. The "oil removed" value in column 5 is after scale pits and therefore should correspond roughly to the total of oils in waste water discharge, sludges, and skimming. The calculations are necessarily rough because specific product data is not available and rolling capacity data must be used. Also, the specific nature of the mills is not known, e.g., whether hot strip mills use rolling oil or cold mills use recirculation.

Inland: Lbs. Oil Based on Column 5 EPA Values

Primary Rolling	8.3×10^6 tons x .76 lbs. oil/ton	=	6.31×10^6
Plate Rolling	$.3 \times 10^6$ tons x 3.10 " "	=	$.93 \times 10^6$
Hot Strip	6.5×10^6 tons x 4.65 " "	=	30.23×10^6
Cold Reduction	5.9×10^6 tons x .13 " "		$.77 \times 10^6$
	Lbs. Oil Total	=	38.24×10^6

This total is multiplied by the ratio of actual production to capacity. In some cases, this will be an estimate of 70%. In this case, 38.24 x 7.3/8.2 = 34.03

Reported Data From Inland (1)

In sludges, trash & debris	-	.534 lbs./mon. x 10
Discharged to water	-	.668 "
Drained, collected, skimmed	-	.430 "
		1.632 lbs./month
		19.58×10^6 lbs./year

This is for the entire plant and to get an estimate for rolling only, we take 90% of this value which equals 17.6×10^6 lbs.

OR 2.4 lbs./ingot ton

Fraction of actual to calculated = 17.6 / 34.03 = .50

(1) The submitted data shows 6×10^6 lbs. oil as reclaimed cold mill lubricant, it is assumed here that this is reclaimed directly and does not constitute raw load to wastewater.

Mill A:

Calculating based on column 5 and using actual production

Primary Rolling	715,000 tons/yr	x .76 lbs. oil/ton	=	543,000 lbs.
Plate Rolling	328,000 "	x 3.10 " "	=	1,017,000
Hot Strip	297,000 "	x 4.65 " "	=	1,381,000
Cold Reduction	13[illegible],000 "	x .13 " "	=	17,000
				2,957,000

Output Data

In sludges, trash & debris	-	538,200	lbs/year
Discharge to water	-	458,400	"
Drained, collected & skimmed	-	1,685,000	"
TOTAL		2,681,600	"

At 90%, this value is 2,413,000 or 3.43/ingot ton

Fraction of actual to calculated - 2,413,000/2,957,000 = .82

Similarly for other mills with sufficient data, we have:

Youngstown:

Primary Rolling	4.5×10^6 tons x .76	=	3.42×10^6	lbs. oil/year	
Plate Rolling					
Hot Strip	3.0×10^6 tons x 4.65	=	13.95×10^6	"	"
Cold Reduction	1.66×10^6 tons x .22	=	$.22 \times 10^6$	"	"
	TOTAL		17.59×10^6	"	"

Multiplying by .7 to correct capacity to production yields 12.31×10^6

From Reported Data:

In sludges, trash and debris	-	1.5×10^6	lbs/mon.
In discharge to waterway	-	$.375 \times 10^6$	"
Drained, collected & skimmed	-	$.390 \times 10^6$	"
TOTAL		2.265×10^6	lbs. oil/mon.

Multiplying by .9 to correct from entire plant to rolling only and multiplying by 12 to convert to yearly basis yields 24.46×10^6 or 6.35 #/ingot ton

Fraction of actual to calculated - 24.46 / 12.31 = 1.99

Calculations for Kaiser for table on page 19

Primary Rolling	*$4.3 \times 10^6 \times .76$ lbs. oil/year	=	3.27×10^6
Plate rolling, incl. Struct & Skelp	$1.6 \times 10^6 \times 3.1$ " "	=	5.00
Hot Strip	$1.5 \times 10^6 \times 4.65$ " "	=	7.00
Cold Reduction	$.8 \times 10^6 \times .13$ " "	=	.10
	Lbs. Oil Total	=	15.37×10^6

Multiplying by 2.4/3.6 (actual prod/capacity) = $10.24\ 10^6$ lbs oil/year

From Reported Data**

In sludges, trash & debris	-	$.0144 \times 10^6$ lbs./mon.
In discharge to waterway	-	$.0012 \times 10^6$ lbs./mon.
Drained, collected & skimmed	-	$.0075 \times 10^6$ lbs./mon.
Total		$.023 \times 10^6$ lbs./mon.

Multiplying by .9 and 12 (see p. 18) yields $.25 \times 10^6$ lbs./year

$$\#\text{oil/ingot ton} = \frac{.25 \times 10^6}{2.4 \times 10^6} = .10$$

Ratio actual oil from rolling operation to EPA guideline calculated; i.e., ACTUAL/CALCULATED (p.19)

$$\frac{.25 \times 10^6}{10.24 \times 10^6} = 0.024$$

Note:

These values are out of proportion to other mills because the values for sludges, waterways, etc., reported by Kaiser are extraordinarily low (and probably wrong)

* From Table 1 of Kaiser submission

** From balance diagram in Kaiser submission

Calculations for Gary for table on page 19

Primary Rolling	$5.2 \times 10^6 \times .76$ lbs. oil/year	=	3.95×10^6
Plate Rolling (incl rail)	$1.25 \times 10^6 \times 3.1$ " "	=	3.88
Hot Strip	$6.0 \times 10^6 \times 4.65$ " "	=	27.90
Cold Reduction	$2.85 \times 10^6 \times .13$ " "	=	.37
	TOTAL	=	36.1

Multiplying 5.1/8.0 (actual prod/capacity) = 23×10^6 lbs. oil/year

From Reported Data**

In sludges, trash & debris	- $.01 \times 10^6$ lbs./mon.
Waterway discharge	- $.10 \times 10^6$ lbs./mon.
Drained, collected & skimmed	- 1.155×10^6 lbs./mon.
Total	- 1.265×10^6 lbs./mon.

Multiplying by .9 and 12 (see page 18) yields - 13.66 lbs oil/year $\times 10^6$

$$\#\text{oil/ingot ton} = \frac{13.66 \times 10^6}{5.1 \times 10^6} = 2.7$$

$$\text{Ratio actual/calc. (page 19)} = \frac{13.66 \times 10^6}{23.0 \times 10^6} = .59$$

Data for Gary for Graph I

% of product as sheet and strip = 60% (Table 1 of Gary submission)

Oil gal/ton - .40 $\frac{2,040,000}{5,100,000}$

Grease lbs./ton - .31 $\frac{130,000 \times 12}{5,100,000}$

Total gal/ton - .44

Total lbs./tou 3.31

Note: This plots out very nicely on Graph I

Following this calculation for other mills, we end up with the following table:

Mill	# Oil/Ingot Ton	Ratio Actual/Calculated	
Inland	2.4	.50	
Mill A	3.4	.82	(known to be on high side because of excess leakage)
Youngstown	6.4	1.99	
J & L	3.4	1.20	
Kaiser	.1	.02	
Republic	1.5	.30	
Bethlehem	2.6	.55	
USS Gary	2.7	.59	
Avg. (Excl. Kaiser)	3.2	.85	

On the average, therefore, there is an indication that the values from column 5 of Table IV are overstated. This is necessarily a very rough perspective because of the limited detail of the data, but it appears that the EPA values are overstated for primary and plate mills and understated for strip mills. Clearly the variation amongst mills is very great and greater detail of mill specifics would be necessary to examine this question more closely.

In making the oil balance, which is our immediate interest, the foregoing is of limited value, but it does indicate that the use of effluent guideline data is not a particularly good source of data for balance purposes.

It is apparent that the product mix of a steel mill will greatly influence the oil balance with respect to total consumption and the percentage of oil in various categories.

Using the data in Table IV, we have constructed Graph I. Naturally, there is great variation due to different practices among mills, but the graph illustrates that oil and grease consumption tends to increase for steel mills have a higher percentage of light product rolling, i.e., hot strip and cold rolling. Mills producing predominantly heavy product tend to have lower consumption. The reason, of course, is that the use of oils especially is higher on strip mills than on plate and structural mills. Certain mills show up with exceptionally high or low consumption in this comparison. Further examination of this fact cannot be done without more detailed data. It is known that Mill A had excessive oil leakage during the period. One might assume that the other mill with high usage, Youngstown, may have a similar problem.

It is apparent, that differences in product, treatment facilities, and oil practice will produce variations in the relative percentages of oil and grease reporting to scale, wastewater, sludges, etc. From the literature for example, some hot mills employ rolling oil and some do not. Some cold rolling mills use recirculation and others do not. Lubrication systems are obviously much more efficient on the newer rolling mills of all types. Review of mill descriptions as presented in the bibliography will provide a general understanding of these factors.

TABLE III

COMPARATIVE DATA ON OIL AND GREASE
CONSUMPTION AND RELATED DATA

(IN LBS./TON)

PROCESS	EPA (1) BPT	EPA RAW (2) LOAD	EPA (3) STUDY	AISI (4) RAW LOAD	OIL (5) REMOVED
CONCAST	.016	.13 - .14	-	-	.12
PRIM. - CAR	.058	.02 - .64	.09	.99	.76
PRIM. - ALY	.102	.03 - .60	-	-	1.10
PRIM. - SECT	.219	.02 - .91	29.8	2.54	3.54
PLATE	.334	.14 -1.25	.95	3.78	3.10
HOT STRIP	.349	.65	-	3.78	4.65
PLATE - ALLOY	.752	.3 -5.5	-	-	-
PIPE & TUBE	.084	0 -2.9	-	-	1.4 - 2.6
COLD MILL:					
RECIRC	.002	.09 -10.5 (RECIRC, COMBO, DIRECT)	-	-	.13
COMBO	.033		.47	-	1.17
DIRECT	.083		-	-	1.59
GALVANIZE	.075	0 - .2	.13	-	.35
TERNE	.075	.04 - .05	-	-	.35

(1) Federal Register, March 29, 1976

(2) Calculated from EPA sampling, from EPA/1-76/048-b Group I, Phase II, Development Document for Interim Final Effluent Limitation Guidelines - Forming, Finishing and Specialty Steel, Vol. I

(3) 12010 DT Q 02/72 Combined Steel Mill and Municipal Wastewaters Treatment

(4) Comments of AISI to EPA on Guidelines for BPT (See Appendix B)

(5) Same as 2, Vol. II calculated using flow/ton and concentration

TABLE IV

Company	% Product as Sheet Strip	% of Total Rolling Capacity: Primary(1)	Bar Rod	Plate	Hot Strip Skelp	Cold(2) Red.	Total (3) (Tons x 10^6)
USS Gary	60	33.8	12.0	3.3	34.5	16.4	17.4
USS South	0	69.0	14.0	17.0	0	0	6.8
Inland	89	38.9	5.6	1.2	28.4	25.9	22.9
Youngstown (Chgo)	94	46.6	5.2	0	31.0	17.2	9.7
Beth. (Sp. Pt.)	86	48.1	3.5	5.5	24.3	18.6	21.4
J&L Aliquippa	77	54.8	10.3	0	18.7	16.2	o.2
Rep. So. Chgo.	0	45.9	54.1	0	0	0	4.7
Interlake (Riv'd)	N.A.	57.1	0	0	32.0	10.9	2.3
Kaiser	73	56.0	0	9.6	24.9	9.5	8.6
Mill "A"	45	50.0	0	19.0	16.0	15.0	2.4

SOURCE: Data sheets submitted by companies except for USS South and Interlake Riverdale which are from 1974 Edition of the AISI Directory of Iron & Steel Works

(1) Includes slab, bloom, billet, rail and structural
(2) Excludes Finishing mills
(3) Total excludes Finishing mills, expressed as 10^6 tons annual capacity. Value in parentheses includes Finishing mills

TABLE V

OIL AND GREASE CONSUMPTION PER TON OF INGOTS (1)

Company	Oil Gal/Ton	Grease Lbs/Ton	Grease Gal/Ton	Total Gal/Ton	Total Lbs/Ton
USS Gary	.40	.31	-	.44	3.3
USS South	.11	.84	-	.22	1.6
Inland	.56	-	-	.56	4.2
Youngstown (Chgo)(2)	1.11	.69	-	1.20	9.0
Beth. (Sp. Pt.)	.47	.72	-	.56	4.3
J&L Aliquippa	.49	1.86	-	.72	5.5
Rep. So. Chgo.	.31	.45	-	.37	2.8
Interlake (Riv'd)	.64	.32	-	.68	5.1
Kaiser	.56	.61	-	.64	4.8
Mill "A"	.70	.38	-	.75	5.6
Average	.54	.69	.09	.61	4.6

(1) Production rate for 1975 for Inland and Kaiser was obtained from Iron Age, April 25, 1977. Production for other mills was taken from data submitted by them, and in some cases is estimated as 70% of capacity. These data are derived from data sheets submitted for each company or from the summary data sheet for those companies not submitting detail sheets. The high grease value for J&L is believed to be a matter of categorizing. Possible differences among company interpretations of oil and grease may exist elsewhere in the data and therefore the total is believed to be more representative for comparison purposes.

(2) Note that there was a mistake in the Youngstown detail data sheet in reversing hydraulic fluid and grease. This created an erroneous input weight on the balance diagram.

VI - A Detailed Analysis of An Example Mill

In making a detailed analysis of a typical small integrated mill, an attempt has been made to approach each estimate from more than one viewpoint.

For oil on product, for example, we can consider the theoretical amount based on references to film thickness of oil films and average gage. We can also consider consumption, recognizing that leakage and other losses are contained in total consumption. We can get some idea from the effluent of secondary processing lines such as galvanizing where the oiled product is cleaned before coating. Given various types of estimates, a final judgement must be made to give the "best" estimate. Throughout the oil balance, all available data including field observation and estimating has been used to derive a composite balance consisting of all the various "best" estimates.

The following calculations and Figures I, II and III portray the balance for this mill. The unaccounted for portion is 2% and is not considered significant in light of the accuracy of the data. This is probably due to a slight error in all the component figures and does not represent a major missing source. The weakest estimate is in the loss to ground leaks, contaminated grease, general clean-up, etc. This value probably is underestimated in the balance. Variations in reclaimed oil data, wastewater and mill scale could also easily account for 2%.

Determination of Oil Balance - Mill A

Input

The input of oils greases and hydraulic fluids are obtained from purchasing records. Greases converted to gallons using a factor of 8 lbs./gallon. These records give the following:

Bulk Grease -	253,000 lbs. or	31,625 gal.
Coating Oil -		58,000 gal.
Hydraulic Oil-		284,000 gal.
Rolling Oil -		31,000 gal.
Gear Oil -		115,000 gal.
Miscellaneous oils -		7,000 gal.
Motor Oils -		5,000 gal.
Miscellaneous Greases -	20,000 lbs. or	2,500 gal
	TOTAL	534,125 gal.

Output

On Products

Several approaches were used to frame a suitable value for this item. The Inland data gives a value of .04 gal/ton, representing the low side. The J & L data (1) gives a value of .30 gal/ton.

From table III, the galvanizing guidelines give a value of 0-.43 gal/ton. Assuming this comes from cleaning oil off strip, it represents another estimate of oil on sheet product.

From Graph II, using an average gage of .050 and a fluid film thickness of .00025, we get a theoretical value of .3 gal/ton for sheet product. Table VII shows the average gage for Mill A product is about .050.

Mill A actual consumption of coating oil was .44 gal/ton product during the period under study.

Obviously, the type of product will influence this value, with generally low (say .04 - .10 gal/ton) values for heavy product, and say .3 - .5 gal/ton for strip product. The J & L value indicates the same range for pipe product.

For Mill A, the calculation is as follows:

Consumption = 58,000 gal & 133,000 tons product
Volatile loss = 22% (see discussion below) = 12,760 gal/year
Assume 10% drippage off product after application = 4,500 gal
Remaining on product as shipped = 40,740 gal (.31 gal/ton)

On Mill Scale

The range of oil content in mill scale from the reported data is great. Values up to 25% are reported, but the weight of data indicates a much lower value:

(1) Based on gal/ton product, assuming product weight is 70% of ingot weight

Inland data	- .4 - .5% oil	(128 #scale/ton ingots)
Mill A Value	- .2 - .5% oil	(103 #scale/ton ingots)
J & L (ref 54, Table II)	.1%	
Armco (ref 43, P 6)	- .3 - .5%	
Youngstown data	- .15 - .4%	

For Mill A, the average is .4% x 103 #scale/ton ingots = 36,800 gal/year

Left on Containers and lost in storage

From a reference on cleaning oil tankers (Ref. not avail).- .1% of oil left in containers such as drums and bulk tanks.

From examination in field, it is believed that relatively good estimates for grease left in containers is 10% in the case of drums and 2% for bulk grease systems. These quantities may be conbusted with the drums if the drums are scrapped or cleaned by a drum reclaimer, and to some extent drop off to the ground and become part of solid waste.

oil:	.1% x 500,000	= 500 gal
drum grease:	10% x 2,500	= 250 gal
bulk grease:	2% x 31,625	= 632 gal
	TOTAL	1,882 gal/year

Leaks and Spills onto ground

This item will be variable depending on oil handling facilities, operating practices and preventive maintenance procedures. From experience at Mill A, an average of about 3 major spills occur on the ground in a year with several more or less regular minor spills in addition. The total loss from these leaks and spills is estimated at 5,000 gal/year. In addition, we have the estimated 2,000 gal/year from drippage off coated product. This oil will eventually find its way into solid waste being cleaned up by slag for the most part. Total in this category is therefore 7,000 gal/year.

Volatilized Burned or Consumed

Table VIII illustrates the results of laboratory tests made to determine the volitalization loss of various types of oils and hydraulic fluids. The four items tested represent 85% of the oils, greases and hydraulic fluids used in Mill A. They also represent the great bulk of the oils which are exposed to elevated temperatures. To translate these tests into an estimate of volatile loss requires estimating the "average" temperature to which the materials are exposed. These estimates are as follows:

Grease - 250° F	% loss (from Graph III)	= 10%
Coating Oil - 200° F	% loss (from Graph III)	= 22%
Hydraulic Oil - 200° F	% loss (from Graph III)	= 11%
Rolling Oil - 250° F	% loss (from Graph III)	= 13.5%

Applying these percentage losses to the quantities of oil for Mill A we have:

Grease 10% volatile loss for 273,000 lbs. or 34,100 gal at 8 lb/gal loss = 3,410 gal

Coating oil	22% loss for	58,000 gal	loss =	12,760 gal
Hydraulic oil	11% loss for	284,000 gal		31,240 gal
Rolling oil	13.5 % loss for	31,000 gal		4,185 gal
		TOTAL VOLATILE LOSS		51,595 gal

Obviously some items would be volatilized to a greater degree because of exposure to high temperatures, such as table roll bearings, hot metal crane lubrication, etc. In other cases, the temperature would be less such as motor room bearings, hydraulic coil handling equipment, etc. The above is presented as a reasonable overall estimate.

In Sludges, Trash & Debris

Sludges:

Calculation of Oil in Sludge - Rolling

Method 1:

Concentrator sludge & clarifier underflow solids = 6.4# ingot ton

At 716,000 NT ingots/year = 6.4 x 716,000 ÷ 2,000 = 2,285 tons/year

At 7% C in sludge = 160 tons carbon
178 tons oil @ 90% C

Method 2:

Underflow is 2,096 mg/L oil and flow is 50 gpm

2096 x 50 x .012 x 300 days/yr ÷ 2000 = 178.7 tons oil/year

Good estimate of oil in sludge therefore is 178 tons/year ± 5%
or 47,500 gals/year (7.9% oil in sludge)

SEE FIGURE I

Calculation of Oil in Sludge - Ironmaking

Oil into clarifier - 8 mg/L
Oil out of clarifier - 1 mg/L

7 mg/L x 2600 gpm x .012 = 218 lb/day = 27.3 gal/day (355 days/year)
10300 gal/year

SEE FIGURE II

Trash and Debris

Oil absorbent 142,000 lbs. @ 20% by weight oil = 3,800 gal/year
Rags 77,000 lbs. @ 10% by weight oil = 1,025 gal/year
Miscellaneous debris from floors, machine shop, degreasing, dirt, scrap metal, etc.
3,000 tons/year at 2% oil (estimated) = 15,000 gal/year
TOTAL = 19,825 gal/year

In Wastewater

Steel Works 3,000 gpm at 5 mg/L = 23 gal/day (from NPDES discharge monitoring)
Other 37,300 gpm at 3 mg/L = 168 gal/day " " "
TOTAL = 57,300 gal/year (300 days/year)

Drained, Collected & Skimmed

Reclaimed oils - direct collection -	- 32,150 gal.	(actual weights)
Reclaimed by cracking - water treatment	- 154,150 gal.	" "
Skimmed & retained on lagoon for future reclaim	- 64,200 gal.	(estimated)
TOTAL	- 250,500 gal.	

The reclaimed oil is used exclusively for fuel, being mixed with #6 fuel oil in the soaking pit oil tanks. Sludge from the reclaim operation is .1% or 186 gal.

Summarizing the balance for Mill A, we have:

Output:

On Products	-	40,740	gal/year	7.6%
On Mill Scale	-	36,800	"	6.9%
Left in Containers	-	1,882	"	.4%
Leaks & Spills	-	7,000	"	1.3%
Volatilized	-	51,595	"	9.7%
In Sludges	-	57,800	"	10.8%
Trash & Debris	-	19,825	"	3.7%
Wastewater Discharge	-	57,300	"	10.7%
Drained, Collected	-	250,500	"	46.9%
TOTAL	-	519,842		98.0%

Input:

TOTAL	-	534,125

Unaccounted for - 2.0%

Table VI

MILL "A" COLD ROLL GAGE BREAKDOWN 1976

Range	Tons	%	$\bar{X}$
.017 - .025	11,393	9%	.021
.0251- .035	29,988	23%	.030
.0351- .045	28,172	21%	[illegible]
.0451- .055	21,416	16%	.050
.0551- .065	18,623	14%	.060
.0651- .075	2,499	2%	.070
.0751- .100	5,190	4%	.087
.100 - .140	14,600	11%	.120
TOTAL	131,611		avg. gage = .052

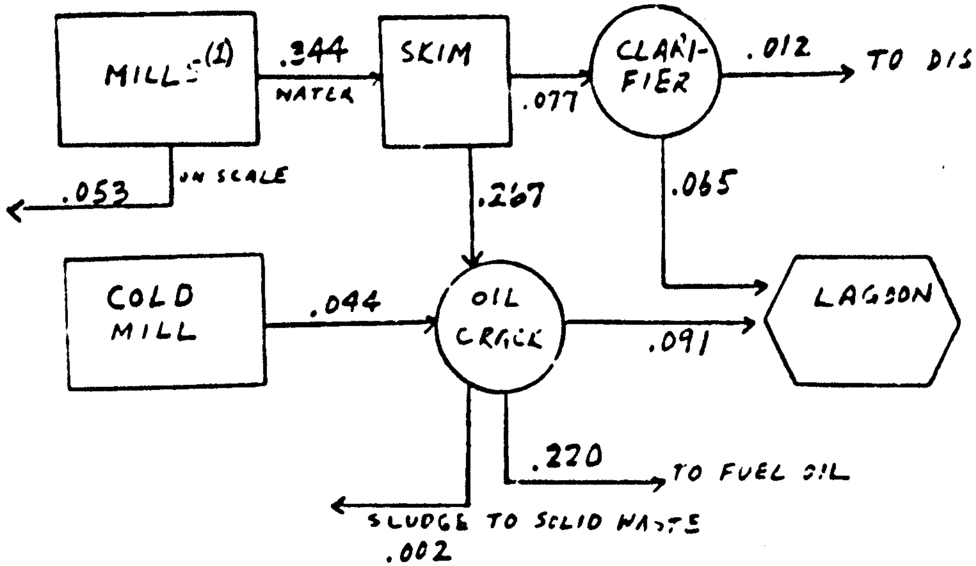
No tin plate production

Table VII

OIL & GREASE WEIGHT LOSS FROM LABORATORY TESTS

	T °F	% Weight loss after 30 minutes
Grease	205° F	4.1%
	271° F	14.8%
Coating Oil	203° F	22.9%
	279° F	54.1%
Hydraulic Oil	203° F	11.4%
	293° F	34.7%
Rolling Oil	203° F	5.1%
	293° F	35.7%

FIG I - BALANCE ON CENTRAL WATER TREATMENT - ROLLING - MILL A



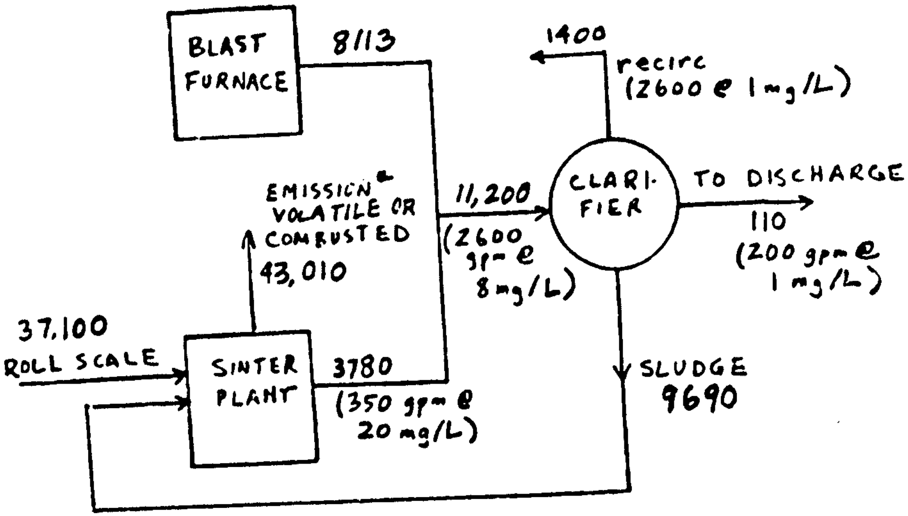
ENTRIES IN GAL/INGOT TON
$.7 \times 10^6$ TONS/YEAR

D-36

Note, these values do not correspond exactly to the figures in the oil balance for Mill A because they are normalized to a production of 700,000 ingot tons/year

(1) Plate mill, Blooming Mill, Hot Strip Mill

FIG II - OIL BALANCE ON BLAST FURNACE AND SINTER PLANT - MILL A



ENTRIES IN gal/yr based on 700,000 tons ingots

* The Bethlehem report indicates 72% of hydrocarbons are emitted as such and 28% either combusted or captured by scrubber.

MILL A data herein shows 8% captured by scrubber (3780/46790)

Note, these values do not correspond exactly to the figures in the oil balance for Mill A because they are normalized to a production of 700,000 ingot tons/year

FIGURE III OIL GREASE AND HYDRAULIC FLUID MATERIAL BALANCE - MILL

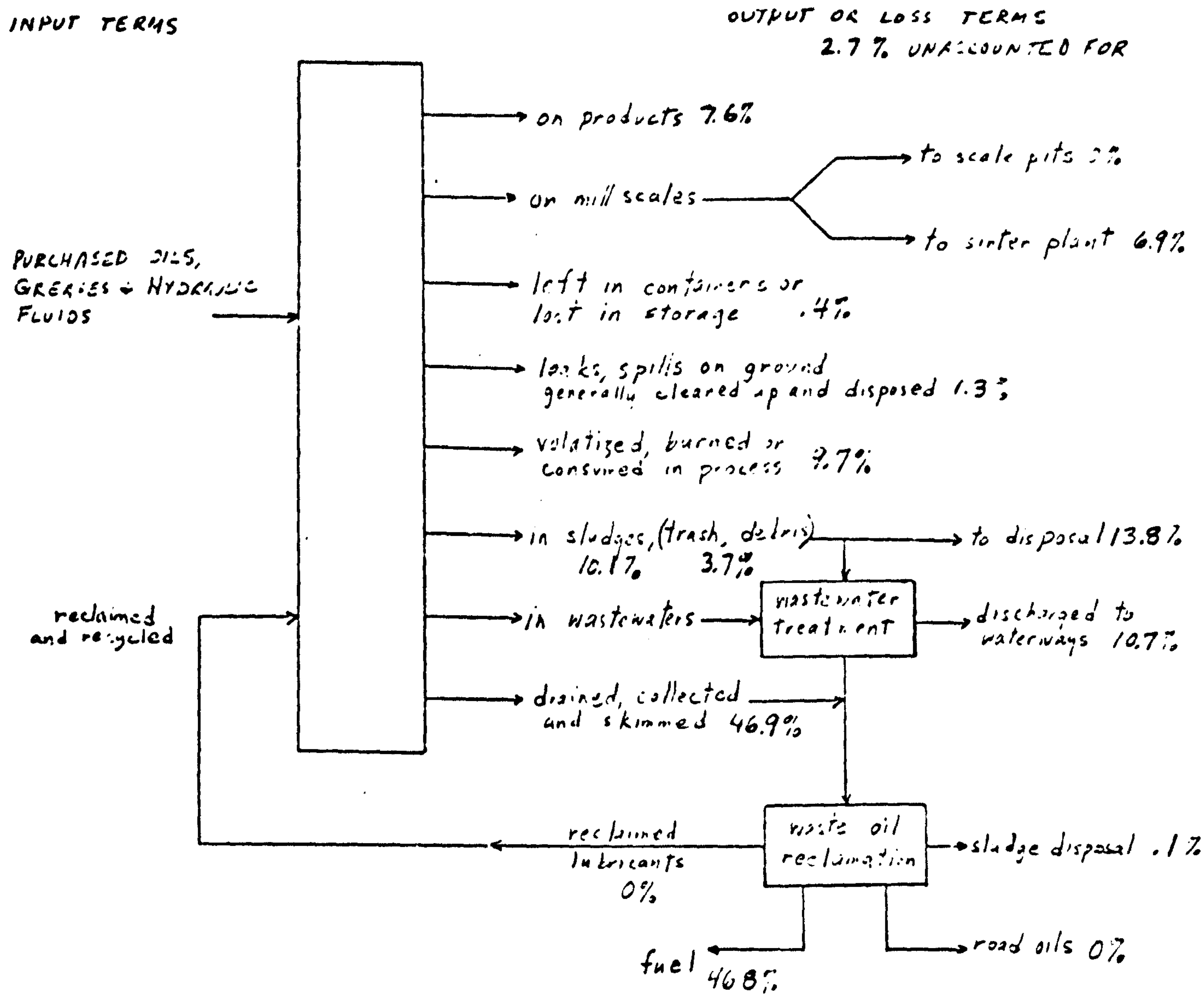


FIGURE IV. OIL BALANCE OF "TYPICAL" MILL

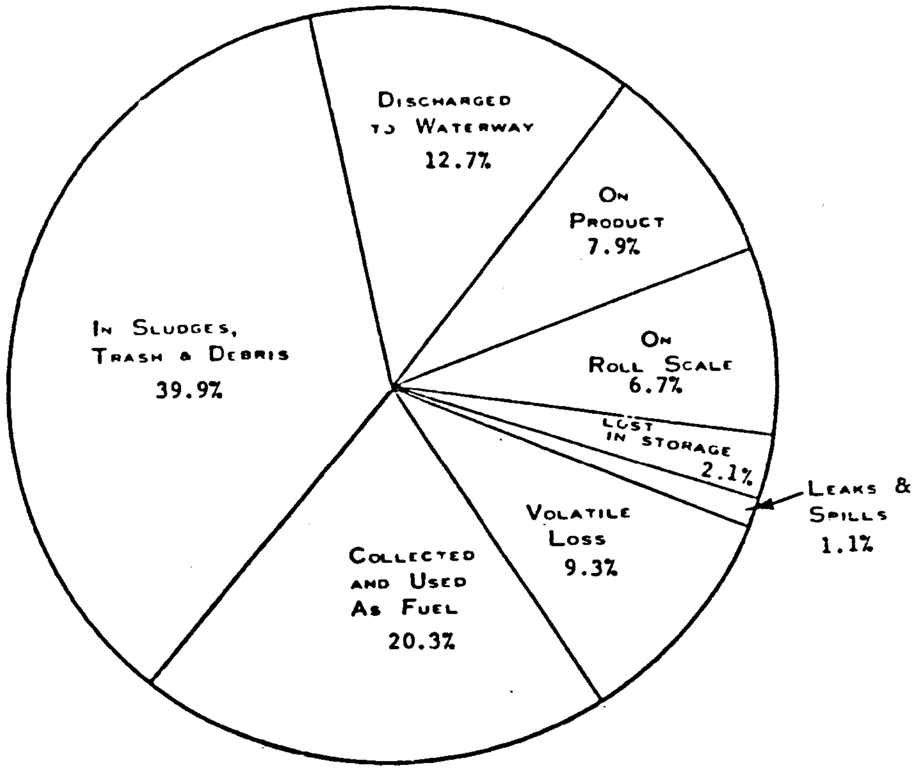


TABLE VII - The Typical Mill

Analysis of the other mills reporting in this study cannot be made as vigorously because the data is not as detailed. Based on the data reported, we have Table VIII.

Additional approximations must be made to develop an overall balance for a typical mill, recognizing that there is no such thing in reality.

For this exercise, the following approximations are used:

Category		Approximation	Resultant %
Product		Average of (1),(3),(4),(6),(7), (8) in Table VIII	7.9%
Scale		Average of (1),(3),(4),(6),(7), (8) in Table VIII	6.7%
Lost		Average of (3) and (7),(8) in Table VIII	2.1%
Leaks		Average of (1),(3),(4),(7),(8) in Table VIII	1.1%
Volatile		(7) adjusted to total 100 in Table VIII	9.3%
Sludges	(39.9)	Average of all but (2). These three are combined as total, the specific breakdown is a function of water treatment facilities.	72.9%
Water	(12.7)		
Collected	(20.3)		
		TOTAL	100.0%

This result is shown pictorially in Figure IV.

These percentages can be translated into pounds per ingot ton or total gallons using the average of 4.6 pounds per ton from Table V. Assume a mill of 4×10^6 ingot ton capacity.

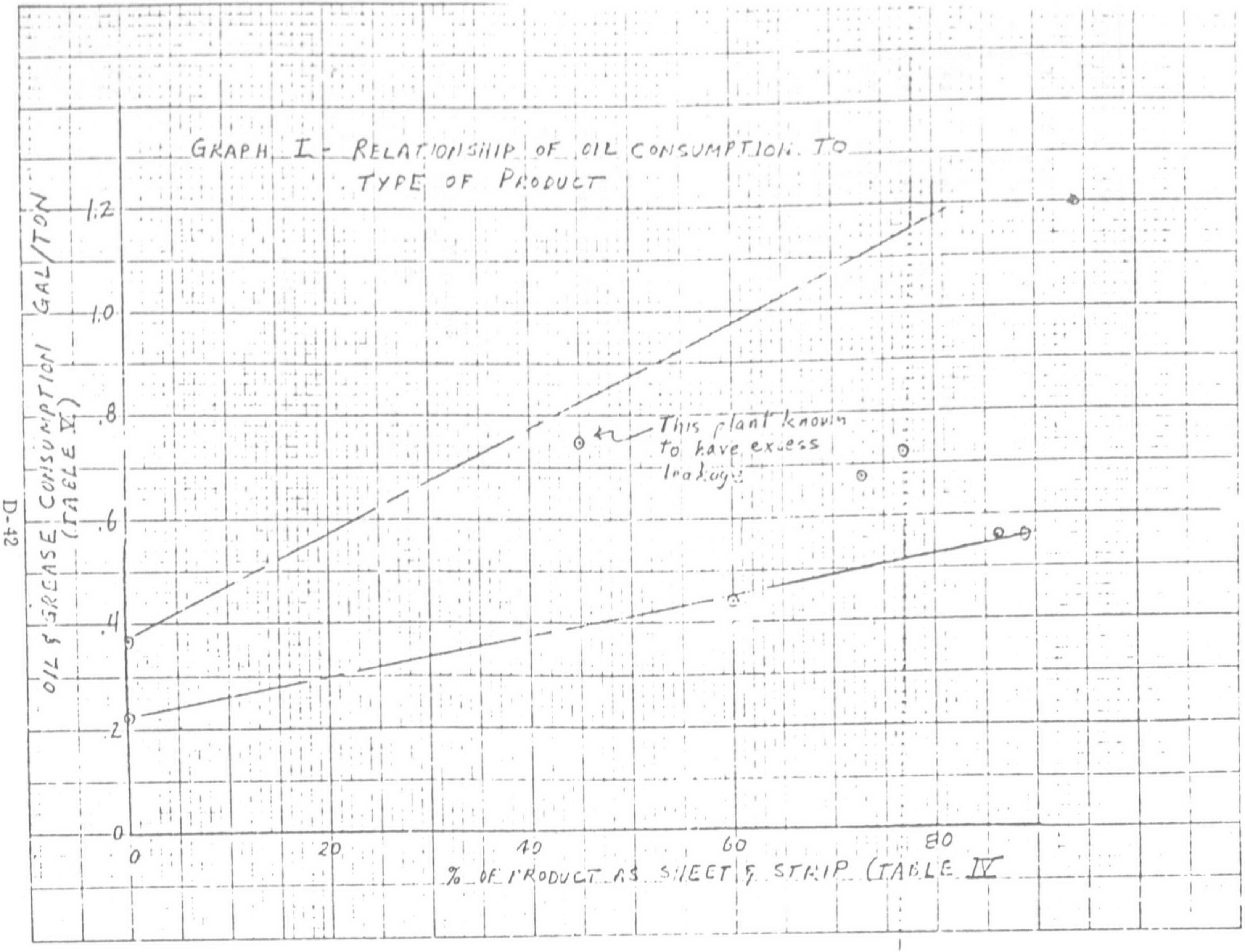
Input		Output	Gallons	#/Ingot Ton
2,453,300 gallons or 4.6 #/ton	TYPICAL MILL 4×10^6 Tons Annual Capacity	→ On Product	193,800	.36
		→ On Scale	164,400	.31
		→ Volatilized	228,100	.43
		→ Lost in Storage	51,500	.10
		→ Leaks & Spills	27,000	.05
		→ Sludges, Trash	978,900	1.84
		→ Discharged	311,500	.58*
		→ Collected	498,000	.93

* Compare this value to column 1 (BPT guidelines) of Table III.

TABLE VIII - Comparison of Oil Balance For Reporting Mills

Category	% of Total Input (See Appendix C for data sheets)							
	Inland (1)	Kaiser (2)	Bethlehem (3)	J&L (4)	Youngstown (5)	Republic (6)	Mill "A" (7)	USS Gary (8)
Product[1]	3.4	.06	4.7	22.6	-	5	7.6 3	3.6
Scale	12.9	38.9	2.3	10.5	4.0	9.3	6.9	1.1
Lost	-	-	5.0	-	-	-	.4	.9
Leaks	.4	-	3.0	.1	-	-	1.3	.7
Volatile	-	-	2.0	.2	-	-	9.7	3.7
Sludges, Debris	19.7	1.5	55	55	51.7	54.7	14.5	29.2
Water	24.6	.1	14	10.2	12.9	7.0	10.7	7.1
Collected	16.0	0	14.7	-	13.4	-	46.9	53.7
Unaccounted	23.0	59.5	-.7	1.4	18.0	24.0	2.0	0

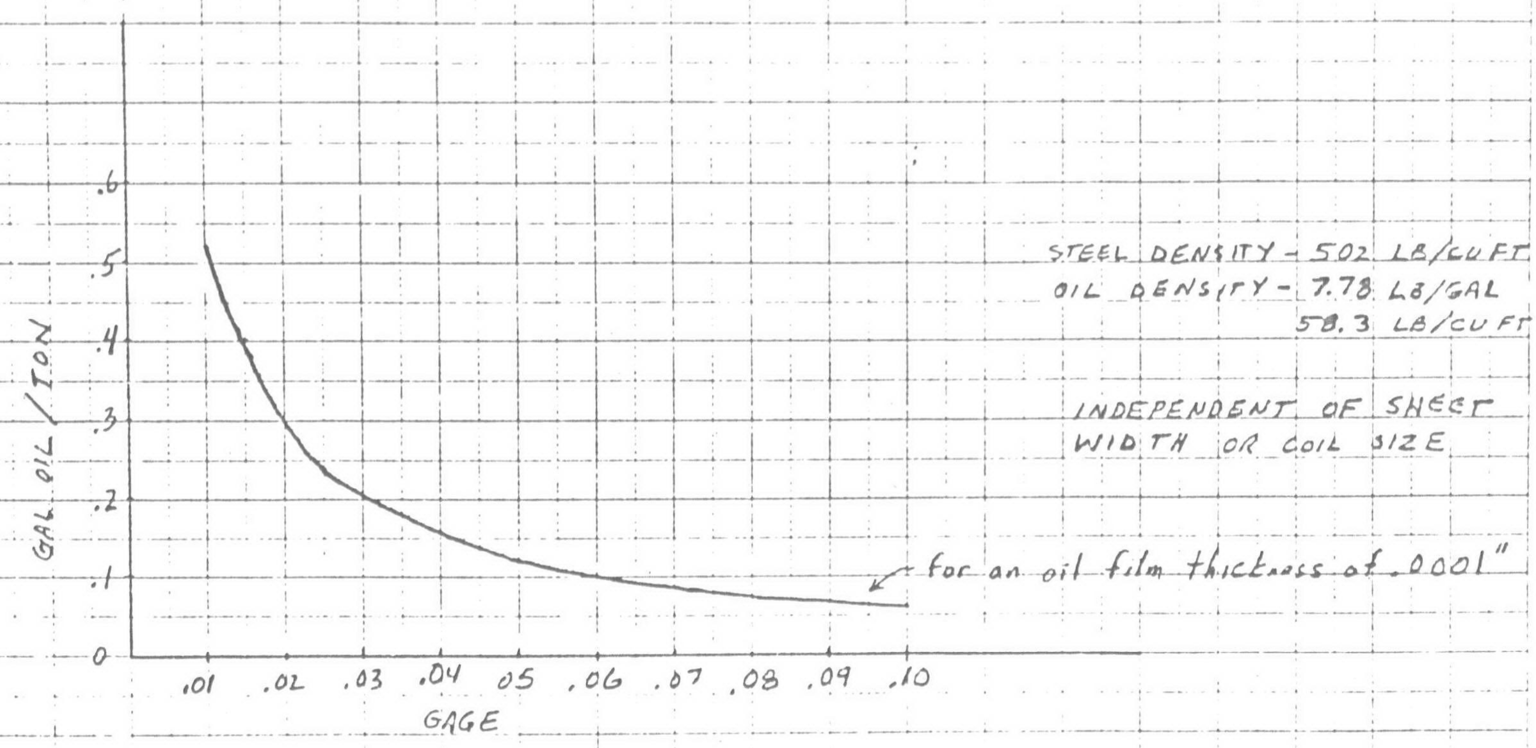
(1) See data sheets in Appendix C for full title of categories.

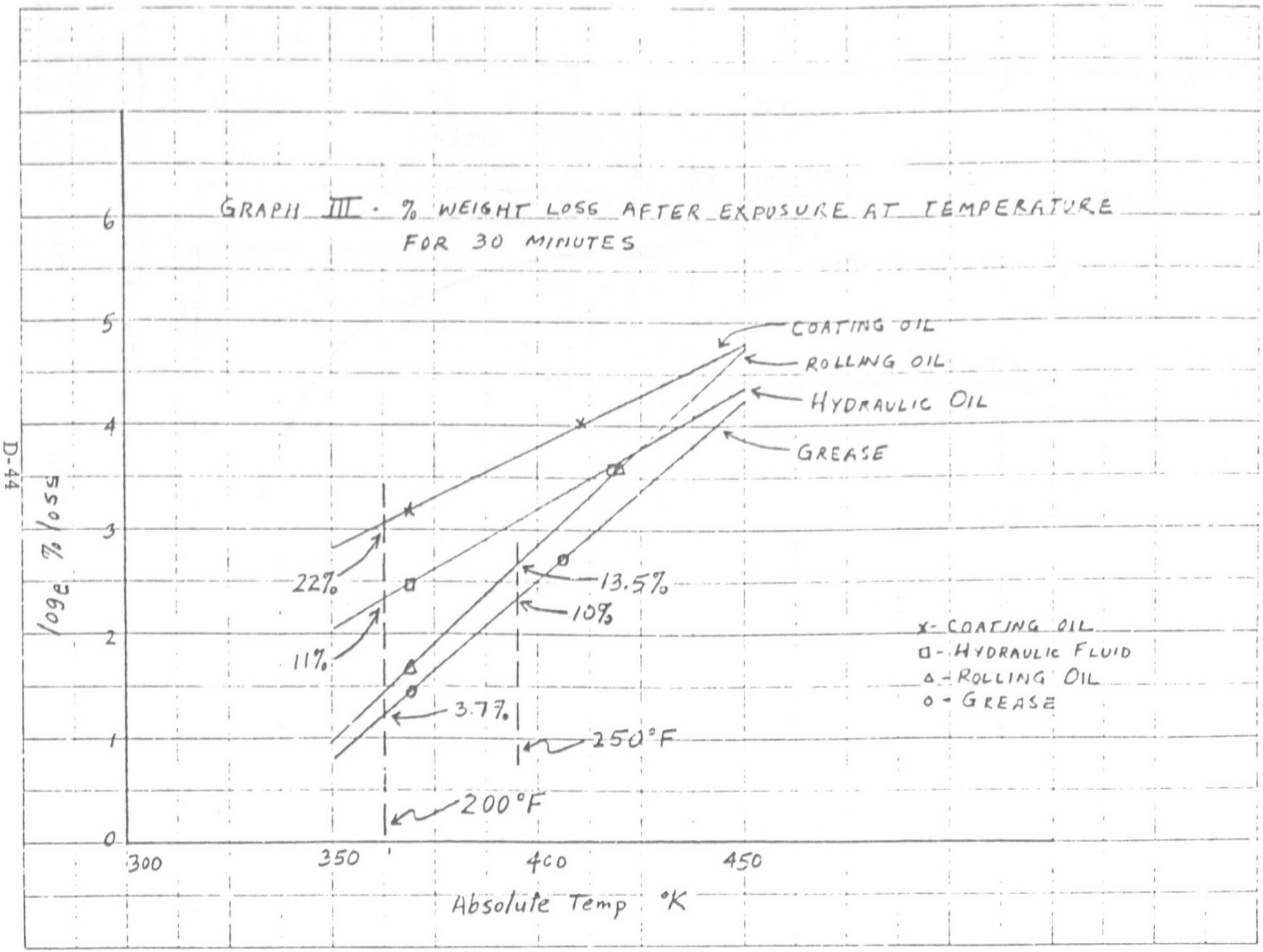


GRAPH I - RELATIONSHIP OF OIL CONSUMPTION TO TYPE OF PRODUCT
OIL & GREASE CONSUMPTION GAL/TON (TABLE V)
1.2
1.0
.8
.6
.4
.2
0
This plant known to have excess leakage
0
20
40
60
80
% OF PRODUCT AS SHEET & STRIP (TABLE IV

GRAPH II

QUANTITY OF COATING OIL AS A FUNCTION OF GAGE ON COLD ROLLED STRIP




GRAPH III · % WEIGHT LOSS AFTER EXPOSURE AT TEMPERATURE FOR 30 MINUTES
loge % loss
0
1
2
3
4
5
6
300
350
400
450
Absolute Temp °K
COATING OIL
ROLLING OIL
HYDRAULIC OIL
GREASE
22%
11%
3.77%
13.5%
10%
250°F
200°F
x - COATING OIL
□ - HYDRAULIC FLUID
Δ - ROLLING OIL
o - GREASE

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