

12.14 Secondary Zinc Processing

12.14.1 General¹

The secondary zinc industry processes scrap metals for the recovery of zinc in the form of zinc slabs, zinc oxide, or zinc dust. There are currently 10 secondary zinc recovery plants operating in the U. S., with an aggregate capacity of approximately 60 megagrams (60 tons) per year.

12.14.2 Process Description²⁻³

Zinc recovery involves 3 general operations performed on scrap, pretreatment, melting, and refining. Processes typically used in each operation are shown in Figure 12.14-1.

12.14.2.1 Scrap Pretreatment -

Scrap metal is delivered to the secondary zinc processor as ingots, rejected castings, flashing, and other mixed metal scrap containing zinc. Scrap pretreatment includes: (1) sorting, (2) cleaning, (3) crushing and screening, (4) sweating, and (5) leaching.

In the sorting operation, zinc scrap is manually separated according to zinc content and any subsequent processing requirements. Cleaning removes foreign materials to improve product quality and recovery efficiency. Crushing facilitates the ability to separate the zinc from the contaminants. Screening and pneumatic classification concentrates the zinc metal for further processing.

A sweating furnace (rotary, reverberatory, or muffle furnace) slowly heats the scrap containing zinc and other metals to approximately 364°C (687°F). This temperature is sufficient to melt zinc but is still below the melting point of the remaining metals. Molten zinc collects at the bottom of the sweat furnace and is subsequently recovered. The remaining scrap metal is cooled and removed to be sold to other secondary processors.

Leaching with sodium carbonate solution converts dross and skimmings to zinc oxide, which can be reduced to zinc metal. The zinc-containing material is crushed and washed with water, separating contaminants from zinc-containing metal. The contaminated aqueous stream is treated with sodium carbonate to convert zinc chloride into sodium chloride (NaCl) and insoluble zinc hydroxide [Zn(OH)₂]. The NaCl is separated from the insoluble residues by filtration and settling. The precipitate zinc hydroxide is dried and calcined (dehydrated into a powder at high temperature) to convert it into crude zinc oxide (ZnO). The ZnO product is usually refined to zinc at primary zinc smelters. The washed zinc-containing metal portion becomes the raw material for the melting process.

12.14.2.2 Melting -

Zinc scrap is melted in kettle, crucible, reverberatory, and electric induction furnaces. Flux is used in these furnaces to trap impurities from the molten zinc. Facilitated by agitation, flux and impurities float to the surface of the melt as dross, and is skimmed from the surface. The remaining molten zinc may be poured into molds or transferred to the refining operation in a molten state.

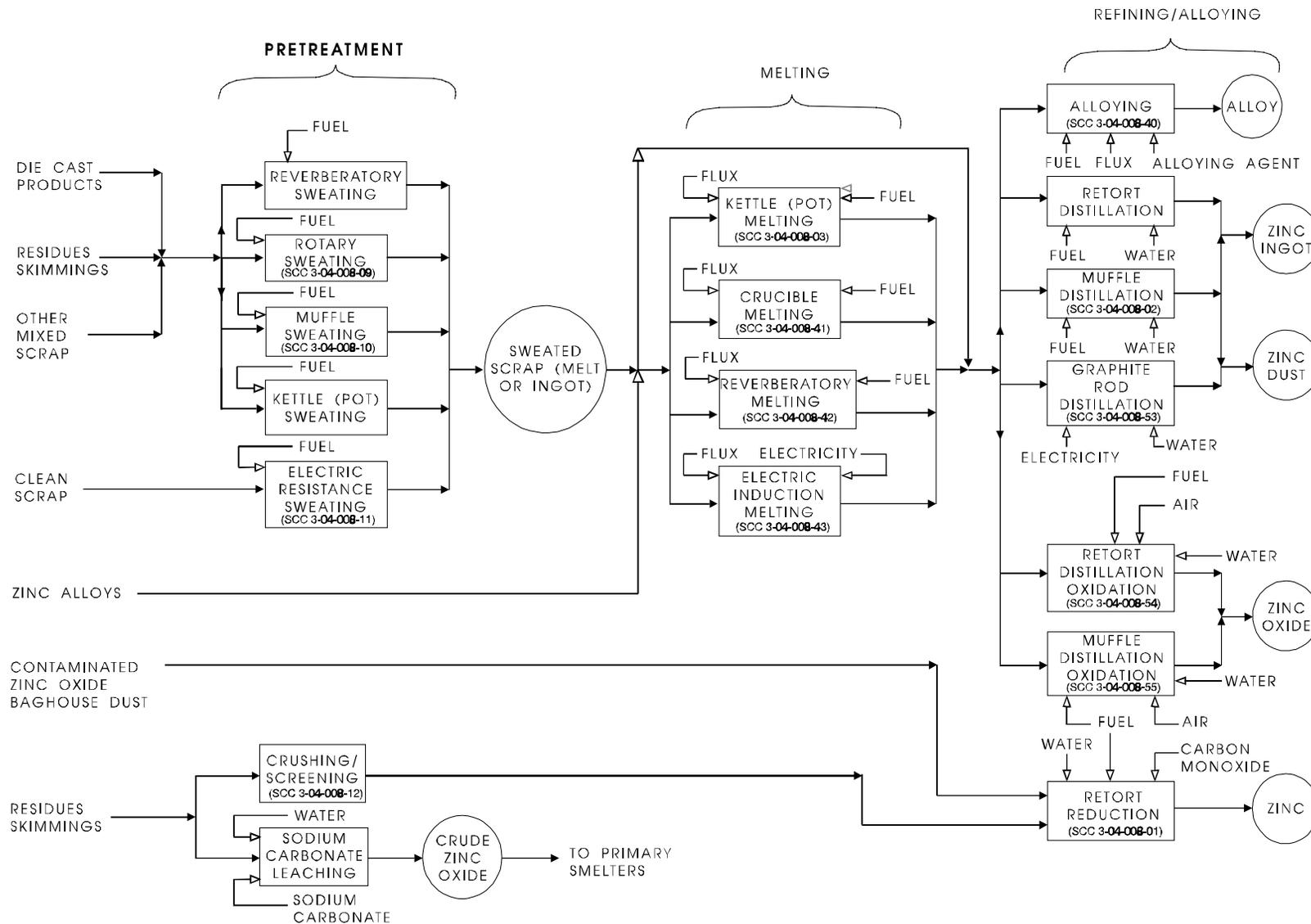


Figure 12.14-1. Process flow diagram of secondary zinc processing. (Source Classification Codes in parentheses.)

Zinc alloys are produced from pretreated scrap during sweating and melting processes. The alloys may contain small amounts of copper, aluminum, magnesium, iron, lead, cadmium, and tin. Alloys containing 0.65 to 1.25 percent copper are significantly stronger than unalloyed zinc.

12.14.2.3 Refining -

Refining processes remove further impurities in clean zinc alloy scrap and in zinc vaporized during the melt phase in retort furnaces, as shown in Figure 12.14-2. Molten zinc is heated until it vaporizes. Zinc vapor is condensed and recovered in several forms, depending upon temperature, recovery time, absence or presence of oxygen, and equipment used during zinc vapor condensation. Final products from refining processes include zinc ingots, zinc dust, zinc oxide, and zinc alloys.

Distillation retorts and furnaces are used either to reclaim zinc from alloys or to refine crude zinc. Bottle retort furnaces consist of a pear-shaped ceramic retort (a long-necked vessel used for distillation). Bottle retorts are filled with zinc alloys and heated until most of the zinc is vaporized, sometimes as long as 24 hours. Distillation involves vaporization of zinc at temperatures from 982 to 1249°C (1800 to 2280°F) and condensation as zinc dust or liquid zinc. Zinc dust is produced by vaporization and rapid cooling, and liquid zinc results when the vaporous product is condensed slowly at moderate temperatures. The melt is cast into ingots or slabs.

A muffle furnace, as shown in Figure 12.14-3, is a continuously charged retort furnace, which can operate for several days at a time. Molten zinc is charged through a feed well that also acts as an airlock. Muffle furnaces generally have a much greater vaporization capacity than bottle retort furnaces. They produce both zinc ingots and zinc oxide of 99.8 percent purity.

Pot melting, unlike bottle retort and muffle furnaces, does not incorporate distillation as a part of the refinement process. This method merely monitors the composition of the intake to control the composition of the product. Specified die-cast scraps containing zinc are melted in a steel pot. Pot melting is a simple indirect heat melting operation where the final alloy cast into zinc alloy slabs is controlled by the scrap input into the pot.

Furnace distillation with oxidation produces zinc oxide dust. These processes are similar to distillation without the condenser. Instead of entering a condenser, the zinc vapor discharges directly into an air stream leading to a refractory-lined combustion chamber. Excess air completes the oxidation and cools the zinc oxide dust before it is collected in a fabric filter.

Zinc oxide is transformed into zinc metal through a retort reduction process using coke as a reducing agent. Carbon monoxide produced by the partial oxidation of the coke reduces the zinc oxide to metal and carbon dioxide. The zinc vapor is recovered by condensation.

12.14.3 Emissions And Controls²⁻⁵

Process and fugitive emission factors for secondary zinc operations are tabulated in Tables 12.14-1, 12.14-2, 12.14-3, and 12.14-4. Emissions from sweating and melting operations consist of particulate, zinc fumes, other volatile metals, flux fumes, and smoke generated by the incomplete combustion of grease, rubber, and plastics in zinc scrap. Zinc fumes are negligible at low furnace temperatures. Flux emissions may be minimized by using a nonfuming flux. In production requiring special fluxes that do generate fumes, fabric filters may be used to collect emissions. Substantial emissions may arise from incomplete combustion of carbonaceous material in the zinc scrap. These contaminants are usually controlled by afterburners.

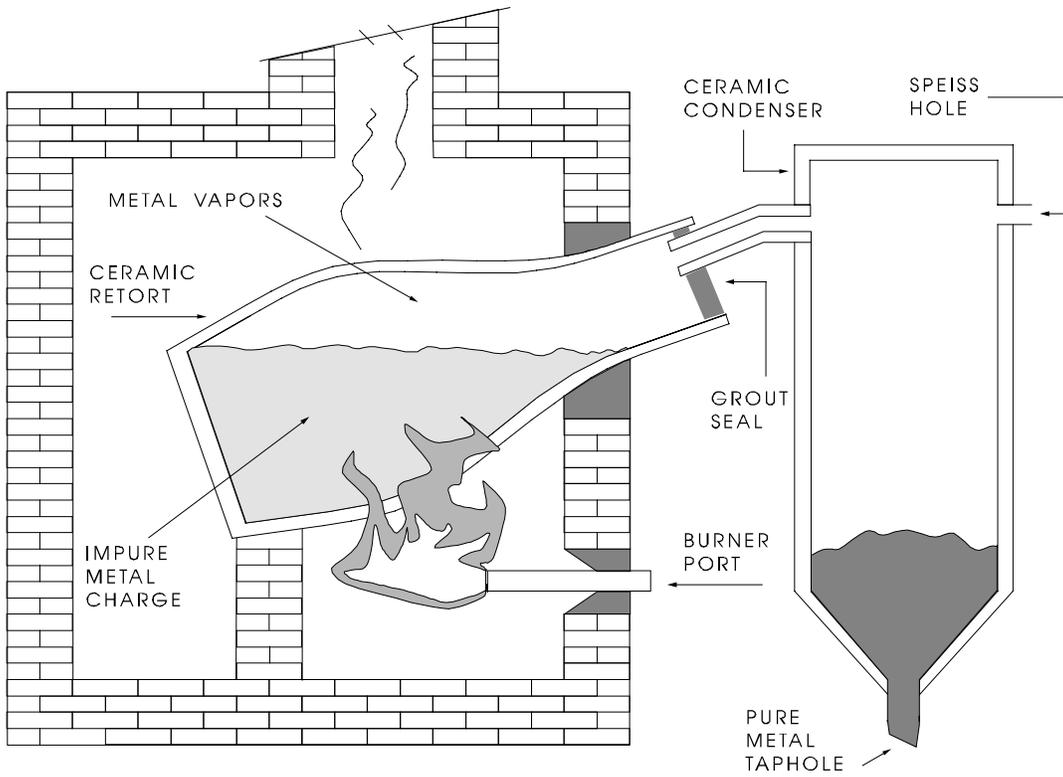


Figure 12.14-2. Zinc retort distillation furnace.

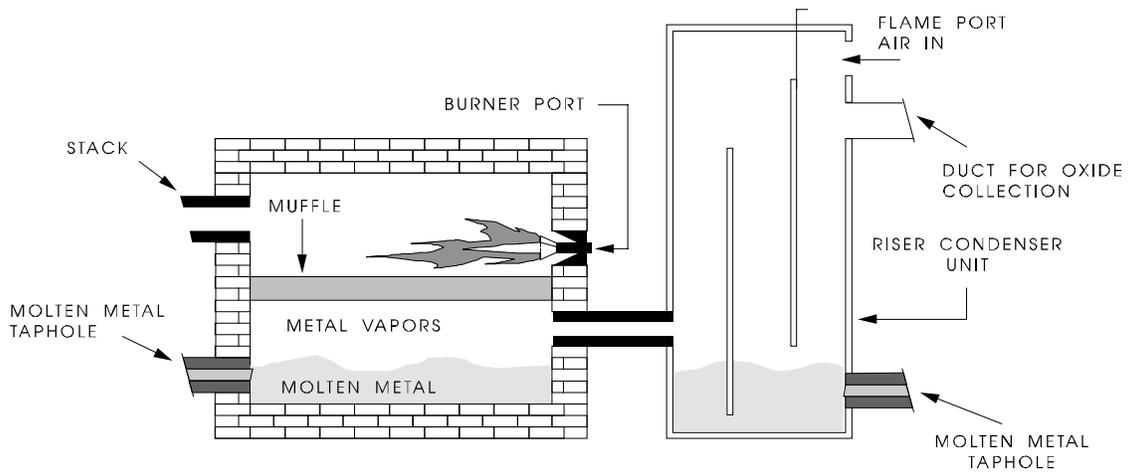


Figure 12.14-3. Muffle furnace and condenser.

Table 12.14-1 (Metric Units). UNCONTROLLED PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING^a

Operation	Emissions	EMISSION FACTOR RATING
Reverberatory sweating ^b (in mg/Mg feed material)		
Clean metallic scrap (SCC 3-04-008-18)	Negligible	C
General metallic scrap (SCC 3-04-008-28)	6.5	C
Residual scrap (SCC 3-04-008-38)	16	C
Rotary sweating ^c (SCC 3-04-008-09)	5.5 - 12.5	C
Muffle sweating ^c (SCC 3-04-008-10)	5.4 - 16	C
Kettle sweating ^b		
Clean metallic scrap (SCC 3-04-008-14)	Negligible	C
General metallic scrap (SCC 3-04-008-24)	5.5	C
Residual scrap (SCC 3-04-008-34)	12.5	C
Electric resistance sweating ^c (SCC 3-04-008-11)	< 5	C
Sodium carbonate leaching calcining ^d (SCC 3-04-008-06)	44.5	C
Kettle pot ^d , mg/Mg product (SCC 3-04-008-03)	0.05	C
Crucible melting (SCC 3-04-008-41)	ND	NA
Reverberatory melting (SCC 3-04-008-42)	ND	NA
Electric induction melting (SCC 3-04-008-43)	ND	NA
Alloying (SCC 3-04-008-40)	ND	NA
Retort and muffle distillation, in kg/Mg of product		
Pouring ^c (SCC 3-04-008-51)	0.2 - 0.4	C
Casting ^c (SCC 3-04-008-52)	0.1 - 0.2	C
Muffle distillation ^d (SCC 3-04-008-02)	22.5	C
Graphite rod distillation ^{c,e} (SCC 3-04-008-53)	Negligible	C
Retort distillation/oxidation ^f (SCC 3-04-008-54)	10 - 20	C
Muffle distillation/oxidation ^f (SCC 3-04-008-55)	10 - 20	C
Retort reduction (SCC 3-04-008-01)	23.5	C
Galvanizing ^d (SCC 3-04-008-05)	2.5	C

^a Factors are for kg/Mg of zinc used, except as noted. SCC = Source Classification Code. ND = no data. NA = not applicable.

^b Reference 4.

^c Reference 5.

^d References 6-8.

^e Reference 2.

^f Reference 5. Factors are for kg/Mg of ZnO produced. All product zinc oxide dust is carried over in the exhaust gas from the furnace and is recovered with 98 - 99% efficiency.

Table 12.14-2 (English Units). UNCONTROLLED PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING^a

Operation	Emissions	EMISSION FACTOR RATING
Reverberatory sweating ^b (in mg/Mg feed material)		
Clean metallic scrap (SCC 3-04-008-18)	Negligible	C
General metallic scrap (SCC 3-04-008-28)	13	C
Residual scrap (SCC 3-04-008-38)	32	C
Rotary sweating ^c (SCC 3-04-008-09)	11 - 25	C
Muffle sweating ^c (SCC 3-04-008-10)	10.8 - 32	C
Kettle sweating ^b		
Clean metallic scrap (SCC 3-04-008-14)	Negligible	C
General metallic scrap (SCC 3-04-008-24)	11	C
Residual scrap (SCC 3-04-008-34)	25	C
Electric resistance sweating ^c (SCC 3-04-008-11)	<10	C
Sodium carbonate leaching calcining ^d (SCC 3-04-008-06)	89	C
Kettle pot ^d , mg/Mg product (SCC 3-04-008-03)	0.1	C
Crucible melting (SCC 3-04-008-41)	ND	NA
Reverberatory melting (SCC 3-04-008-42)	ND	NA
Electric induction melting (SCC 3-04-008-43)	ND	NA
Alloying (SCC 3-04-008-40)	ND	NA
Retort and muffle distillation, in lb/ton of product		
Pouring ^c (SCC 3-04-008-51)	0.4 - 0.8	C
Casting ^c (SCC 3-04-008-52)	0.2 - 0.4	C
Muffle distillation ^d (SCC 3-04-008-02)	45	C
Graphite rod distillation ^{c,e} (SCC 3-04-008-53)	Negligible	C
Retort distillation/oxidation ^f (SCC 3-04-008-54)	20 - 40	C
Muffle distillation/oxidation ^f (SCC 3-04-008-55)	20 - 40	C
Retort reduction (SCC 3-04-008-01)	47	C
Galvanizing ^d (SCC 3-04-008-05)	5	C

^a Factors are for lb/ton of zinc used, except as noted. SCC = Source Classification Code.

ND = no data. NA = not applicable.

^b Reference 4.

^c Reference 5.

^d References 6-8.

^e Reference 2.

^f Reference 5. Factors are for lb/ton of ZnO produced. All product zinc oxide dust is carried over in the exhaust gas from the furnace and is recovered with 98 - 99% efficiency.

Table 12.14-3 (Metric Units). FUGITIVE PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING^a

Operation	Emissions	EMISSION FACTOR RATING
Reverberatory sweating ^b (SCC 3-04-008-61)	0.63	E
Rotary sweating ^b (SCC 3-04-008-62)	0.45	E
Muffle sweating ^b (SCC 3-04-008-63)	0.54	E
Kettle (pot) sweating ^b (SCC 3-04-008-64)	0.28	E
Electrical resistance sweating, per kg processed ^b (SCC 3-04-008-65)	0.25	E
Crushing/screening ^c (SCC 3-04-008-12)	2.13	E
Sodium carbonate leaching (SCC 3-04-008-66)	ND	NA
Kettle (pot) melting furnace ^b (SCC 3-04-008-67)	0.0025	E
Crucible melting furnace ^d (SCC 3-04-008-68)	0.0025	E
Reverberatory melting furnace ^b (SCC 3-04-008-69)	0.0025	E
Electric induction melting ^b (SCC 3-04-008-70)	0.0025	E
Alloying retort distillation (SCC 3-04-008-71)	ND	NA
Retort and muffle distillation (SCC 3-04-008-72)	1.18	E
Casting ^b (SCC 3-04-008-73)	0.0075	E
Graphite rod distillation (SCC 3-04-008-74)	ND	NA
Retort distillation/oxidation (SCC 3-04-008-75)	ND	NA
Muffle distillation/oxidation (SCC 3-04-008-76)	ND	NA
Retort reduction (SCC 3-04-008-77)	ND	NA

^a Reference 9. Factors are kg/Mg of end product, except as noted. SCC = Source Classification Code. ND = no data. NA = not applicable.

^b Estimate based on stack emission factor given in Reference 2, assuming fugitive emissions to be equal to 5% of stack emissions.

^c Reference 2. Factors are for kg/Mg of scrap processed. Average of reported emission factors.

^d Engineering judgment, assuming fugitive emissions from crucible melting furnace to be equal to fugitive emissions from kettle (pot) melting furnace.

Particulate emissions from sweating and melting are most commonly recovered by fabric filter. In 1 application on a muffle sweating furnace, a cyclone and fabric filter achieved particulate recovery efficiencies in excess of 99.7 percent. In 1 application on a reverberatory sweating furnace, a fabric filter removed 96.3 percent of the particulate. Fabric filters show similar efficiencies in removing particulate from exhaust gases of melting furnaces.

Table 12.14-4 (English Units). FUGITIVE PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING^a

Operation	Emissions	EMISSION FACTOR RATING
Reverberatory sweating ^b (SCC 3-04-008-61)	1.30	E
Rotary sweating ^b (SCC 3-04-008-62)	0.90	E
Muffle sweating ^b (SCC 3-04-008-63)	1.07	E
Kettle (pot) sweating ^b (SCC 3-04-008-64)	0.56	E
Electrical resistance sweating, per ton processed ^b (SCC 3-04-008-65)	0.50	E
Crushing/screening ^c (SCC 3-04-008-12)	4.25	E
Sodium carbonate leaching (SCC 3-04-008-66)	ND	NA
Kettle (pot) melting furnace ^b (SCC 3-04-008-67)	0.005	E
Crucible melting furnace ^d (SCC 3-04-008-68)	0.005	E
Reverberatory melting furnace ^b (SCC 3-04-008-69)	0.005	E
Electric induction melting ^b (SCC 3-04-008-70)	0.005	E
Alloying retort distillation (SCC 3-04-008-71)	ND	NA
Retort and muffle distillation (SCC 3-04-008-72)	2.36	E
Casting ^b (SCC 3-04-008-73)	0.015	E
Graphite rod distillation (SCC 3-04-008-74)	ND	NA
Retort distillation/oxidation (SCC 3-04-008-75)	ND	NA
Muffle distillation/oxidation (SCC 3-04-008-76)	ND	NA
Retort reduction (SCC 3-04-008-77)	ND	NA

^a Reference 9. Factors are lb/ton of end product, except as noted. SCC = Source Classification Code. ND = no data. NA = not applicable.

^b Estimate based on stack emission factor given in Reference 2, assuming fugitive emissions to be equal to 5% of stack emissions.

^c Reference 2. Factors are for lb/ton of scrap processed. Average of reported emission factors.

^d Engineering judgment, assuming fugitive emissions from crucible melting furnace to be equal to fugitive emissions from kettle (pot) melting furnace.

Crushing and screening operations are also sources of dust emissions. These emissions are composed of zinc, aluminum, copper, iron, lead, cadmium, tin, and chromium. They can be recovered by hooded exhausts used as capture devices and can be controlled with fabric filters.

The sodium carbonate leaching process emits zinc oxide dust during the calcining operation (oxidizing precipitate into powder at high temperature). This dust can be recovered in fabric filters, although zinc chloride in the dust may cause plugging problems.

Emissions from refining operations are mainly metallic fumes. Distillation/oxidation operations emit their entire zinc oxide product in the exhaust gas. Zinc oxide is usually recovered in fabric filters with collection efficiencies of 98 to 99 percent.

References For Section 12.14

1. *Mineral Commodity Summaries 1992*, U. S. Department Of Interior, Bureau Of Mines.
2. William M. Coltharp, *et al.*, *Multimedia Environmental Assessment Of The Secondary Nonferrous Metal Industry*, Draft, EPA Contract No. 68-02-1319, Radian Corporation, Austin, TX, June 1976.
3. John A. Danielson, *Air Pollution Engineering Manual*, 2nd Edition, AP-40, U. S. Environmental Protection Agency, Research Triangle Park, NC, 1973. Out of Print.
4. W. Herring, *Secondary Zinc Industry Emission Control Problem Definition Study (Part I)*, APTD-0706, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.
5. H. Nack, *et al.*, *Development Of An Approach To Identification Of Emerging Technology And Demonstration Opportunities*, EPA-650/2-74-048, U. S. Environmental Protection Agency, Cincinnati, Ohio, May 1974.
6. G. L. Allen, *et al.*, *Control Of Metallurgical And Mineral Dusts And Fumes In Los Angeles County*, Report Number 7627, U. S. Department Of The Interior, Washington, DC, April 1952.
7. *Restricting Dust And Sulfur Dioxide Emissions From Lead Smelters*, VDI Number 2285, U. S. Department Of Health And Human Services, Washington, DC, September 1961.
8. W. F. Hammond, *Data On Nonferrous Metallurgical Operations*, Los Angeles County Air Pollution Control District, Los Angeles, CA, November 1966.
9. *Assessment Of Fugitive Particulate Emission Factors For Industrial Processes*, EPA-450/3-78-107, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1978.
10. *Source Category Survey: Secondary Zinc Smelting And Refining Industry*, EPA-450/3-80-012, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1980.