

12.6 Primary Lead Smelting

12.6.1 General¹⁵

Lead is found naturally as a sulfide ore containing small amounts of copper, iron, zinc, precious metals, and other trace elements. The lead in this ore, typically after being concentrated at or near the mine (see Section 12.18), is processed into metallurgical lead at 4 facilities in the U. S. (2 smelters/refineries in Missouri, 1 smelter in Montana, and 1 refinery in Nebraska). Demand for lead from these primary sources is expected to remain relatively stable in the early 1990s, due in large part to storage battery recycling programs being implemented by several states. Significant emissions of sulfur dioxide (SO₂), particulate matter, and especially lead have caused much attention to be focused on identifying, and quantifying emissions from, sources within these facilities.

12.6.2 Process Description^{15,16}

The processing of lead concentrate into metallurgical lead involves 3 major steps: sintering, reduction, and refining. A diagram of a typical facility, with particle and gaseous emission sources indicated, is shown in Figure 12.6-1.

12.6.2.1 Sintering -

The primary purpose of the sinter machine is the reduction of sulfur content of the feed material. This feed material typically consists of the following:

1. Lead concentrates, including pyrite concentrates that are high in sulfur content, and concentrates that are high in impurities such as arsenic, antimony, and bismuth, as well as relatively pure high-lead-concentrates;
2. Lime rock and silica, incorporated in the feed to maintain a desired sulfur content;
3. High-lead-content sludge byproducts from other facilities; and
4. Undersized sinter recycled from the roast exiting the sinter machine.

The undersized sinter return stream mixes with the other feed components, or green feed, as the 2 streams enter a rotary pelletizing drum. A water spray into the drum enhances the formation of nodules in which the sinter returns form a core rich in lead oxide and the green feed forms a coating rich in lead sulfide. The smaller nodules are separated out and conveyed through an ignition furnace, then covered with the remaining nodules on a moving grate and conveyed through the sinter machine, which is essentially a large oven. Excess air is forced upward through the grate, facilitating combustion, releasing SO₂ and oxidizing the lead sulfide to lead oxide. The "strong gas" from the front end of the sinter machine, containing 2.5 to 4 percent SO₂, is vented to gas cleaning equipment before possibly being piped to a sulfuric plant. Gases from the rear part of the sinter machine are recirculated up through the moving grate and are typically vented to a baghouse. That portion of the product which is undersized, usually due to insufficient desulfurization, is filtered out and recycled through the sinter; the remaining sinter roast is crushed before being transported to the blast furnace.

12.6.2.2 Reduction -

The sinter roast is then conveyed to the blast furnace in charge cars along with coke, ores containing high amounts of precious metals, slags and byproducts dusts from other smelters, and byproduct dusts from baghouses and various other sources within the facility. Iron scrap is often added to the charge to aid heat distribution and to combine with the arsenic in the charge. The blast furnace process rate is controlled by the proportion of coke in the charge and by the air flow through the tuyeres in the floor of the furnace. The charge descends through the furnace shaft into the smelting zone, where it becomes molten, and is tapped into a series of settlers that allow the separation of lead from slag. The slag is allowed to cool before being stored, and the molten lead of roughly 85 percent purity is transported in pots to the dross building.

12.6.2.3 Refining -

The drossing area consists of a variety of interconnected kettles, heated from below by natural gas combustion. The lead pots arriving from the blast furnace are poured into receiving kettles and allowed to cool to the point at which copper dross rises to the top of the top and can be skimmed off and transferred to a reverberatory furnace. The remaining lead dross is transferred to a finishing kettle where such materials as wood chips, coke fines, and sulfur are added and mixed to facilitate further separation, and this sulfur dross is also skimmed off and transferred to the reverberatory furnace. To the drosses in the reverberatory furnace are added tetrahedrite ore, which is high in silver content but low in lead and may have been dried elsewhere within the facility, coke fines, and soda ash. When heated in the same fashion as the kettles, the dross in the reverberatory furnace separates into 3 layers: lead bullion settles to the bottom and is tapped back to the receiving kettles, and matte (copper sulfide and other metal sulfides), which rises to the top, and speiss (high in arsenic and antimony content) are both typically forwarded to copper smelters.

The third and final phase in the processing of lead ore to metallurgical lead, the refining of the bullion in cast iron kettles, occurs in 5 steps: (1) removal of antimony, tin, and arsenic; (2) removal of precious metals by Parke's Process, in which zinc combines with gold and silver to form an insoluble intermetallic at operating temperatures; (3) vacuum removal of zinc; (4) removal of bismuth by the Betterson Process, in which calcium and magnesium are added to form an insoluble compound with the bismuth that is skimmed from the kettle; and (5) removal of remaining traces of metal impurities through the adding of NaOH and NaNO₃. The final refined lead, from 99.990 to 99.999 percent pure, is typically cast into 45 kilogram (100 pound) pigs for shipment.

12.6.3 Emissions And Controls¹⁵⁻¹⁷

Emissions of lead and particulate occur in varying amounts from nearly every process and process component within primary lead smelter/refineries, and SO₂ is also emitted from several sources. The lead and particulate emissions point, volume, and area sources may include:

1. The milling, dividing, and fire assaying of samples of incoming concentrates and high-grade ores;
2. Fugitive emissions within the crushing mill area, including the loading and unloading of ores and concentrates from rail cars onto conveyors;
3. The ore crushers and associated transfer points, which may be controlled by baghouses;
4. Fugitive emissions from the unloading, storage, and transfer of byproduct dusts, high-grade ores, residues, coke, lime, silica, and any other materials stored in outdoor piles;

5. Strong gases from the front end of the sinter machine, which are typically vented to an electrostatic precipitator (ESP), 1 or more scrubbers, and a wet ESP for sulfuric acid mist elimination, but during shutdowns of the acid plant may bypass the ESP;
6. Weak gases from the back end of the sinter machine, which are high in lead dust content but typically pass through cyclones and a baghouse;
7. Fugitive emissions from the sinter building, including leaks in the sinter machine and the sinter cake crusher;
8. Gases exiting the top of the blast furnace, which are typically controlled with a baghouse;
9. Fugitive emissions from the blast furnace, including leaks from the furnace covers and the bottoms of charge cars, dust from the charge car bottom dump during normal operation, and escaping gases when blow holes develop in the shaft and must be "shot" with explosives;
10. Lead fumes from the molten lead and slag leaving the blast furnace area;
11. Fugitive leaks from the tapping of the kettles and settlers;
12. The hauling and dumping of slag, at both the handling and cooling area and the slag storage pile;
13. The combustion of natural gas, as well as the creation of lead-containing fumes at the kettles and reverberatory furnace, all of which are typically vented to a baghouse at the dressing building;
14. Fugitive emissions from the various pouring, pumping, skimming, cooling, and tapping operations within the dressing building;
15. The transporting, breaking, granulating, and storage of speiss and matte;
16. The loading, transferring, and drying of tetrahedrite ore, which is typically controlled with cyclones and a baghouse;
17. The periodic cleanout of the blast and reverberatory furnaces; and
18. Dust caused by wind erosion and plant vehicular traffic, which are normally estimated with factors from Section 13.2 of AP-42, but are addressed herein due to the high lead content of the dust at primary lead smelting and refining facilities.

Tables 12.6.1 and 12.6.2 present particulate, PM-10, lead, and SO₂ emission factors for primary lead smelting.

Table 12.6-1 (Metric Units). EMISSION FACTORS FOR PRIMARY LEAD SMELTING^a

EMISSION FACTOR RATING: E

Process	Particulate ^b	PM-10 ^c	Lead	SO ₂
Ore crushing ^d (SCC 3-03-010-04)	0.023	0.018	0.001	NA
Ore screening ^e (SCC 3-03-010-27)	0.004	0.005	0.001	NA
Tetrahedrite drier ^f (SCC 3-03-010-28)	0.012	0.013	0.0003	NA
Sinter machine (weak gas) ^g (SCC 3-03-010-29)	0.051	0.052	0.009	275 ^h
Sinter building fugitives ^g (SCC 3-03-010-25)	0.118	0.058	0.016	NA
Sinter storage ^j (SCC 3-03-010-30)	NA	NA	NA	NA
Blast furnace ^k (SCC 3-03-010-02)	0.21	0.43	0.034	23 ^h
Speiss pit ^m (SCC 3-03-010-31)	NA	NA	NA	NA

^a Most of the processes are controlled by baghouses; otherwise it is noted. SCC = Source Classification Code. NA = not applicable.

^b Filterable particulate only.

^c Filterable and condensable particulate; $\leq 10 \mu\text{m}$ mean diameter.

^d Entire ore crushing building at one facility, including transfer points; kg/Mg of ore, except lead, which is kg/Mg of lead in ore.

^e Tests at one facility; kg/Mg ore.

^f kg/Mg dried; tests at one facility.

^g kg/Mg sinter produced; tests at one facility. The sinter machine is controlled by ESP and scrubbers.

^h Uncontrolled emission factor from 1971 tests on two facilities (References 5 and 6).

^j kg/Mg throughput; includes charge car loading; from tests at one facility.

^k kg/Mg of bullion, includes dross kettles; from tests at one facility.

^m kg/Mg granulated; from tests at one facility.

Table 12.6-2 (English Units). EMISSION FACTORS FOR PRIMARY LEAD SMELTING^a

EMISSION FACTOR RATING: E

Process	Particulate ^b	PM-10 ^c	Lead	SO ₂
Ore crushing ^d (SCC 3-03-010-04)	0.0445	0.036	0.002	NA
Ore screening ^e (SCC 3-03-010-27)	0.007	0.009	0.002	NA
Tetrahdrite drier ^f (SCC 3-03-010-28)	0.023	0.026	0.0006	NA
Sinter machine (weak gas) ^g (SCC 3-03-010-29)	0.10	0.104	0.019	550 ^h
Sinter building fugitives ^g (SCC 3-03-010-25)	0.24	0.117	0.032	NA
Sinter storage ^j (SCC 3-03-010-30)	NA	NA	NA	NA
Blast furnace ^k (SCC 3-03-010-02)	0.43	0.863	0.067	45 ^h
Speiss pit ^m (SCC 3-03-101-31)	NA	NA	NA	NA

^a Most of the processes are controlled by baghouses; otherwise it is noted. SCC = Source Classification Code. NA = not applicable.

^b Filterable particulate only.

^c Filterable and condensable particulate; ≤10 μm mean diameter.

^d Entire ore crushing building at one facility, including transfer points; lb/ton of ore, except lead, which is lb/ton of lead in ore.

^e Tests at one facility; lb/ton ore.

^f lb/ton dried; tests at one facility.

^g lb/ton sinter produced; tests at one facility. The sinter machine is controlled by ESP and scrubbers.

^h Uncontrolled emission factor from 1971 tests on two facilities (5,6).

^j lb/ton throughput; includes charge car loading; from tests at one facility.

^k lb/ton of bullion, includes dross kettles; from tests at one facility.

^m lb/ton granulated; from tests at one facility.

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