A TECHNICAL AND COMMERCIAL REFERENCE



HOT-DIP GALVANIZING

Science, Operations & Profitable Management

Process, Plant Design, Operations and Business.
From Zero to Start-Up.

ALADDIN MOHAMMED

B.Sc. Metallurgy & Materials Engineering | MBA × 2 | PMP

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The Critical Upper Limit: 0.007% Al

Above approximately 0.007% aluminum, the bath behaviour changes for the worse:

- The aluminum reacts aggressively with the zinc-ammonium chloride flux, producing **black flux marks** on the coating surface that customers will reject
- The reaction with chloride produces sticky residues at the bath surface that collect on incoming work
- Risk of bare spots increases, because the aluminum oxide film at the steel-zinc interface can prevent proper bonding

Operators recognise high-aluminum conditions by the appearance of the bath surface: sticky, foamy, with persistent black marks on processed work. The fix is to dilute the bath by processing high tonnage through it without further aluminum additions. In severe cases, partial bath replacement is required.

This is the operational tension in aluminum control: enough to suppress ash and improve brightness, never too much to attack the flux. The window is narrow, 0.002% to 0.005%, and disciplined daily addition is the only way to stay inside it.



Figure 6.2: Galvanizing in operation. A large pipe section suspended in the kettle during the dip. Work of this size is handled on multiple suspension points to keep it controlled and draining, and the flange face is angled so that zinc has a free edge to run from rather than a flat surface to pool on. The bath surface has been skimmed immediately before this dip, which is why the zinc around the work is bright rather than covered in ash.
Photographed at one of the author's galvanizing plants.

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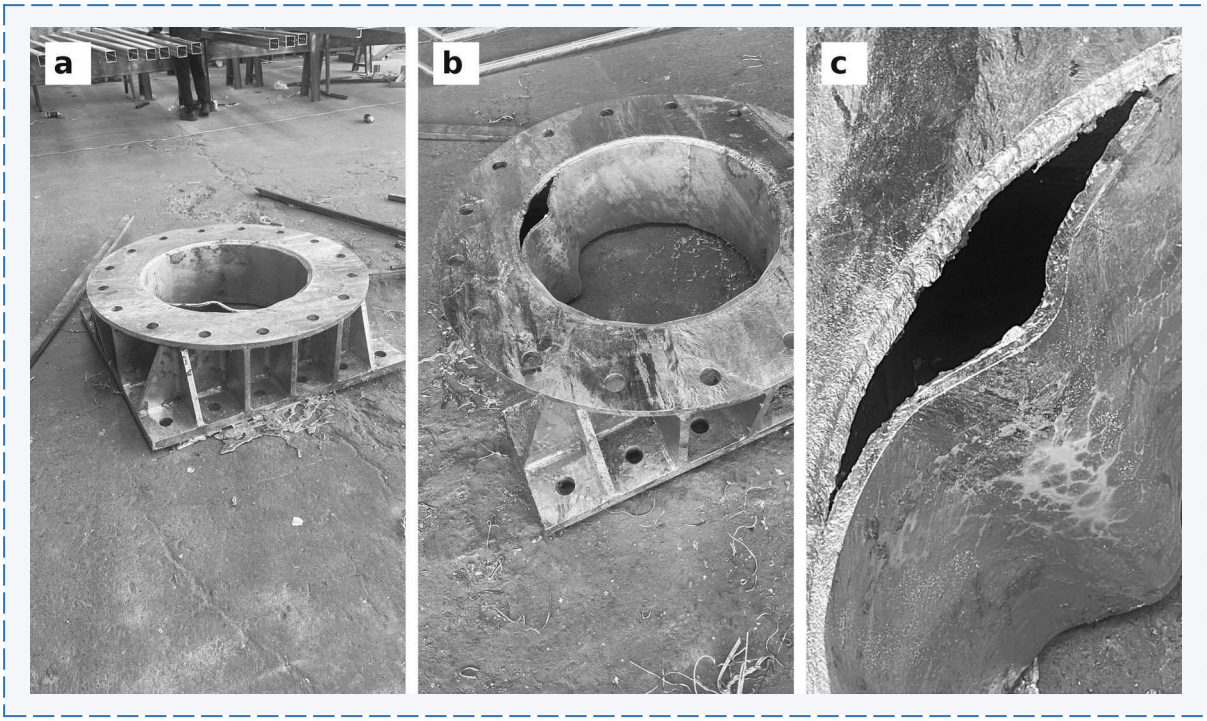

Figure 9.3: What an unvented enclosed section does in the bath. (a) A heavy ring and hub assembly after galvanizing, with frozen zinc still lying on the concrete around its base, which is what was thrown out of the cavity. (b) The hub seen from above: the wall has torn open along a curved split running most of the way around one side. (c) The split at close range, with the fracture edge and the coating that ran into it clearly visible. No vent or drain opening was provided to the enclosed volume, so trapped moisture flashed to steam on immersion and the section failed at its weakest line. The assembly is scrap. Nothing about this outcome is a galvanizing fault: it was decided on the drawing.

Photographed at one of the author's galvanizing plants.

Vent holes prevent this. They are not optional. They are not aesthetic. They are a safety system.

9.4.2 Why Drainage Matters: Coating, Cost, and Dimension

Drainage holes serve a different function. As work is withdrawn from the kettle, molten zinc inside hollow sections must drain out before it solidifies. Without adequate drainage:

- The piece is heavy and unbalanced, and a 6 m hollow box may carry 50–200 kg of trapped zinc
- Internal lumps form at the low points, affecting dimensional accuracy and downstream assembly
- The customer pays for zinc that delivers no protection, which is pure waste
- The internal coating is uneven, with thick zones where pooled zinc froze and thin zones where it drained late

Drainage and venting are usually combined: a hole that admits air during immersion also drains zinc during withdrawal. The discipline at design stage is to verify that **every enclosed volume has a clear path for fluid to flow in at the bottom and air to escape at the top** during the kettle dip.

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Table 9.6: Fabricator's pre-galvanizing checklist

#	Check	Standard reference	Confirmed
4	Welding flux residues removed mechanically	ASTM A385	☐
5	Anti-spatter silicone-free or removed mechanically	ASTM A385	☐
6	All vent holes per ISO 14713-2 and ASTM A385 sizing	ISO 14713-2 cl. 6.5 / ASTM A385	☐
7	All drainage holes per ISO 14713-2 and ASTM A385 sizing	ISO 14713-2 cl. 6.5 / ASTM A385	☐
8	Internal baffles cropped or holed	ISO 14713-2 / ASTM A385	☐
9	Overlapping plates: ≤2.5 mm seal-welded, >2.5 mm vented per Section 9.5.3	ASTM A385 / ISO 14713-2	☐
10	Symmetrical geometry to control distortion; thickness ratios reasonable	ASTM A384	☐
11	Cope cuts and HSS corners conditioned with weld bead where required	ASTM A385	☐
12	High-strength steels (UTS >1,200 MPa) flagged for blast cleaning instead of pickling	ASTM A143	☐
13	Fasteners specified per A153 or EN ISO 10684; thread fit addressed (overtapped nuts)	ASTM A153 / EN ISO 10684	☐
14	Lifting points designed into structure	ASTM A385	☐
15	Masking requirements identified and discussed with galvanizer	ASTM A385	☐
16	Identification markings stamped, drilled, or welded, not paint or marker	Operational	☐
17	Single-dip against progressive dipping decision documented	ASTM A385	☐
18	Drawings reviewed by galvanizer at design stage	ISO 14713-2 cl. 4	☐
19	Customer informed of expected coating appearance and acceptance basis	ASTM A123 / ISO 1461	☐
20	Surface free of paint, primer, silicone, oil-based markers, and mill coatings	ASTM A385 / Ch.5	☐

A copy of this checklist accompanies every batch of work delivered to the plant. The receiving inspector reviews it as part of the receiving inspection (Chapter 5, Section 5.1). Where items are incomplete, the work is held pending correction.

This checklist also forms part of **Appendix B, Design Checklist for Fabricators**, which expands each line into the underlying rationale and the specific clause of the governing standard.

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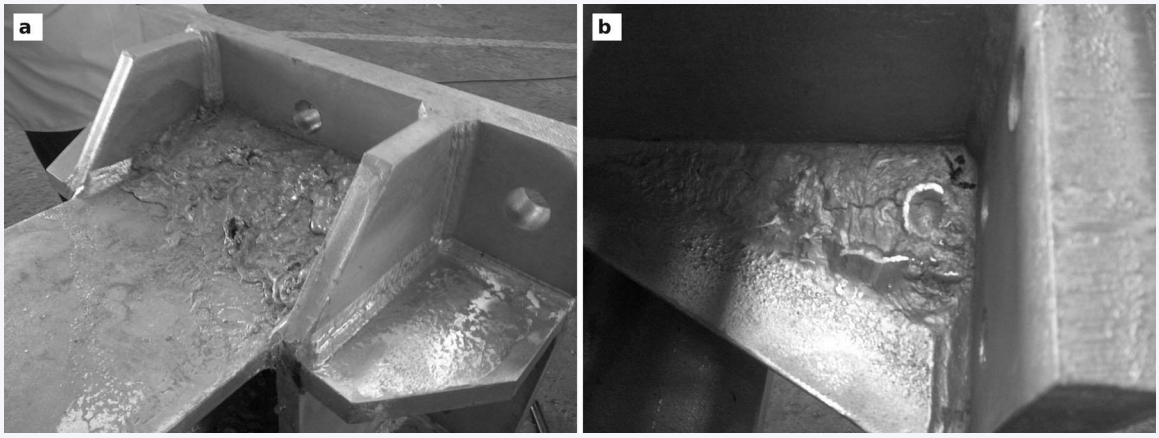

Figure 10.5 (a, b): Excess zinc frozen in the low points of a fabricated assembly, a drainage-geometry failure. (a) Drainage holes were provided in the gusset plates, but too few and too small for the channel they served; molten zinc collected in the trough and solidified rather than draining clear on withdrawal. (b) Close-up of the resulting frozen zinc mass in a corner pocket with no escape route, where the wrinkled surface is zinc that ran inward and froze in place. The cause is upstream, on the drawing board and at the fabrication shop (Chapter 9), and it arrives as a coating defect at the kettle.
Photographed at one of the author's galvanizing plants.



Figure 10.6: Welding spatter galvanized in place. The cluster of small rounded nodules along the weld toe is weld spatter that was not removed before the work entered the chemical line; the zinc coated over it, leaving permanent raised beads. Under ASTM A123/A123M-24 clause 6.4 these are a defect only where they interfere with the intended use of the article, on a faying or mating surface for example. Prevention is at the fabrication shop (Chapter 9): chip or grind spatter off before dispatch. The blue mark is an inspector's flag locating the area.
Photographed at one of the author's galvanizing plants.

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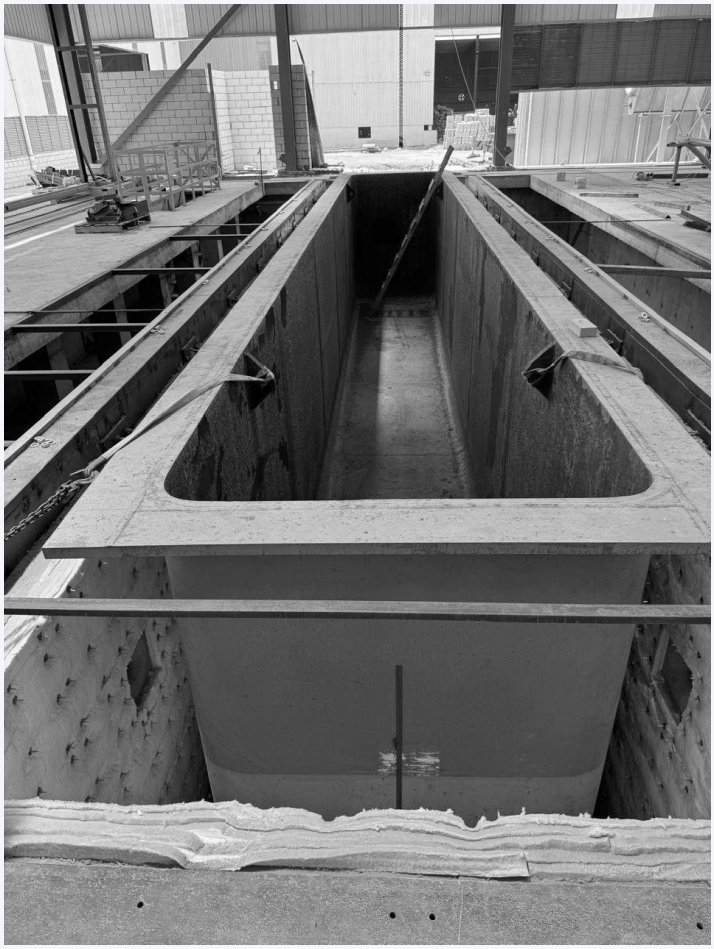

Figure 17.2: The galvanizing kettle being lowered into its furnace pit during installation. The vessel is slung from lifting straps at the rim and guided down into the enclosure; the studded pattern on the pit walls is the refractory anchoring, and the pale fibrous material banked at the base is ceramic-fibre insulation. Setting the kettle is the heaviest single lift of the build, and the vessel is levelled precisely against the crane rail before the furnace structure and burners are closed up around it, because once the furnace is built the kettle position can no longer be adjusted.
Photographed at one of the author's galvanizing plants.

Check the following at kettle setting:

- **Longitudinal alignment**: kettle centreline parallel to crane rail
- **Transverse level**: kettle rim level across the width; maximum permitted deviation is typically 2 mm
- **Longitudinal level**: along the kettle length; same tolerance
- **Rim height**: confirm working lip height against the crane hook height calculation; this determines maximum article depth

These checks are made by surveyor after the kettle is seated but before the furnace structure is built around it. Once the furnace is installed, the kettle position cannot be adjusted without demolishing the furnace structure.

17.3.4 Tank Line Installation

The pre-treatment tank line must be installed in a straight line with consistent spacing. The spacing between tanks is not aesthetic. It is functional. The jig, with articles hanging from it, must clear the tank walls when being moved from one tank to the next by the crane.

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20.2 Zinc Consumption Benchmarks

The primary performance metric in zinc cost management is **zinc consumption as a percentage of galvanized steel weight**. This single ratio captures the combined effect of coating weight, dross generation, and ash production.

20.2.1 Batch Galvanizing Benchmarks

For a well-managed batch galvanizing plant processing structural steel:

Table 20.1: Batch galvanizing benchmarks

Metric	Target (Well-Managed)	Warning Zone	Problem Zone
Total zinc consumption	5–7% of galvanized steel weight	7–9%	>9%
Coating zinc (on product)	70–75% of zinc consumed	65–70%	<65%
Dross + ash combined	25–30% of zinc consumed	30–40%	>40%
Dross alone	13–16% of zinc consumed	16–20%	>20%
Ash alone	12–15% of zinc consumed	15–18%	>18%

My own working reference points, carried consistently through this book and through the pricing model in Chapter 19, are **dross at 15% of zinc consumed** and **ash at 14% of zinc consumed**, for a combined loss of **29%** and a coating yield of **71%**.

These benchmarks assume normal structural steel chemistry (Si below 0.04% or in the Sebisty range of 0.15 to 0.22%), bath temperature maintained at 445 to 460°C, and regular dross removal on a weekly schedule.

20.2.2 Know Your Denominator

This is the single most common source of confused zinc numbers in the industry, and it causes real commercial damage when two parties quote figures that appear to disagree but describe exactly the same physical plant.

Dross and ash can be expressed against three different denominators, and all three are legitimate:

Table 20.2: Zinc streams by denominator

Stream	% of zinc consumed	% of coating zinc	% of steel weight (at 6% consumption)
Coating on product	71%	100%	4.26%
Dross	**15%**	21%	0.90%
Ash	**14%**	20%	0.84%
Dross + ash	**29%**	**41%**	**1.74%**

The same plant, the same month, the same physical kilograms. A manager quoting "29% loss" and a supplier quoting "41% loss" may be in complete agreement. **This book uses percentage of zinc consumed as the standard basis throughout.** The free Zinc Consumption Calculator on hdgcommunity.com expresses the same loss against coating

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D.4.1 Zinc balance

Table D.2: Reconciliation form: zinc balance

#	Line item	Unit	This month	Year to date
1	Opening zinc inventory, bath	kg		
2	Zinc ingots received	kg		
3	Alloy additions received, Al, Bi, Ni	kg		
4	**Total zinc available** (1 + 2 + 3)	kg		
5	Closing zinc inventory, bath	kg		
6	**Total zinc consumed** (4 − 5)	kg		

D.4.2 Where the consumed zinc went

Table D.3: Reconciliation form: where the consumed zinc went

#	Line item	Unit	This month	% of line 6	YTD
7	Zinc on product, pickup	kg			
8	Dross removed and weighed	kg			
9	Ash removed and weighed	kg			
10	**Accounted zinc** (7 + 8 + 9)	kg			
11	**Unaccounted variance** (6 − 10)	kg			

D.4.3 Production and performance

Table D.4: Reconciliation form: production and performance

#	Line item	Unit	This month	YTD
12	Steel processed	MT		
13	Zinc consumption rate (6 ÷ 12 ÷ 1,000 × 100)	% of steel weight		
14	Pickup (7 ÷ 12 ÷ 1,000 × 100)	% of steel weight		
15	Coating yield (7 ÷ 6 × 100)	% of zinc consumed		
16	Dross (8 ÷ 6 × 100)	% of zinc consumed		
17	Ash (9 ÷ 6 × 100)	% of zinc consumed		
18	Dross plus ash combined (16 + 17)	% of zinc consumed		

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E.9.3 Total cost and floor

Table E.11: Worked example: total cost and floor

Line	Component	Value
T1	Variable	856
T2	Fixed	700
T3	**Total cost per tonne**	**1,556**
T4	Target margin	25% of selling price
T5	**Floor price** = 1,556 ÷ 0.75	**2,075**, rounded to 2,100

E.9.4 Tier rates from the base

Table E.12: Worked example: tier rates from the base

Tier	Multiplier	Rate
1, above 12 mm	1.00×	2,100
2, 6 to 12 mm	1.125×	2,363
3, 3 to 6 mm	1.30×	2,730
4, below 3 mm	1.65×	3,465

Multipliers shown are midpoints of the indicative ranges. Calibrate to your own consumption data.

E.9.5 What the stack shows

Zinc and fixed cost recovery together account for 1,273 of the 1,556 total, better than four fifths. Chemicals, fuel and wire together come to 83, about 5%.

A plant that halves its chemical spend saves 15 per tonne. A plant that lifts throughput from 500 to 1,000 tonnes a month saves 350. **Manage the large numbers.**

E.10 Sensitivity: The Two Levers That Matter

Rerun the model against both before setting a rate card, because they dominate every other variable in it.

E.10.1 Throughput

Holding everything else at the worked example:

Table E.13: Sensitivity to throughput

Monthly volume	Fixed/tonne	Total cost	Floor at 25% margin
300 MT	1,167	2,023	2,697
500 MT	700	1,556	2,075
1,000 MT	350	1,206	1,608
2,000 MT	175	1,031	1,375
4,000 MT	88	944	1,259

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