



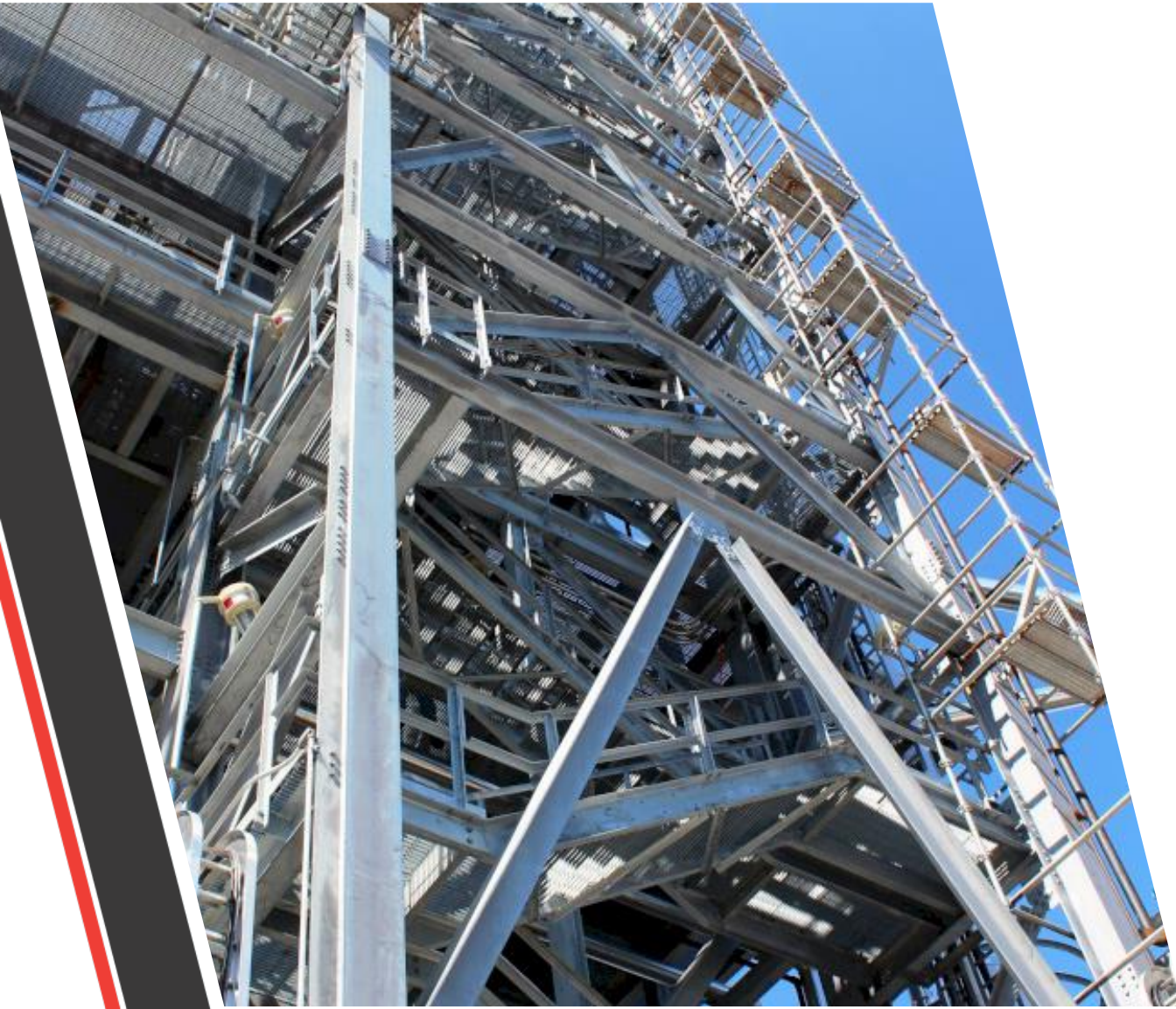
DESIGNING FOR HOT-DIP GALVANIZING

February 12, 2020
Williamsburg, VA

LEARNING OBJECTIVES

- ▶ Upon seminar completion, you will be able to:
 - ▶ Understand the need for communication throughout the design process
 - ▶ Identify best design practices for products to be galvanized based on ASTM specification guidelines
 - ▶ Avoid fabrication and design issues that subtract from long-term corrosion protection

WHY SPECIFY HOT-DIP GALVANIZING



- Corrosion Protection
- Durability
- Longevity
- Availability/Versatility
- Aesthetics
- Sustainability
 - Environmental
 - Economical

***Galvani
ze It!***



**GOVERNOR MARIO M.
CUOMO BRIDGE**

Tarrytown, • 2017



HOT-DIP GALVANIZING

Surface Preparation, Galvanizing

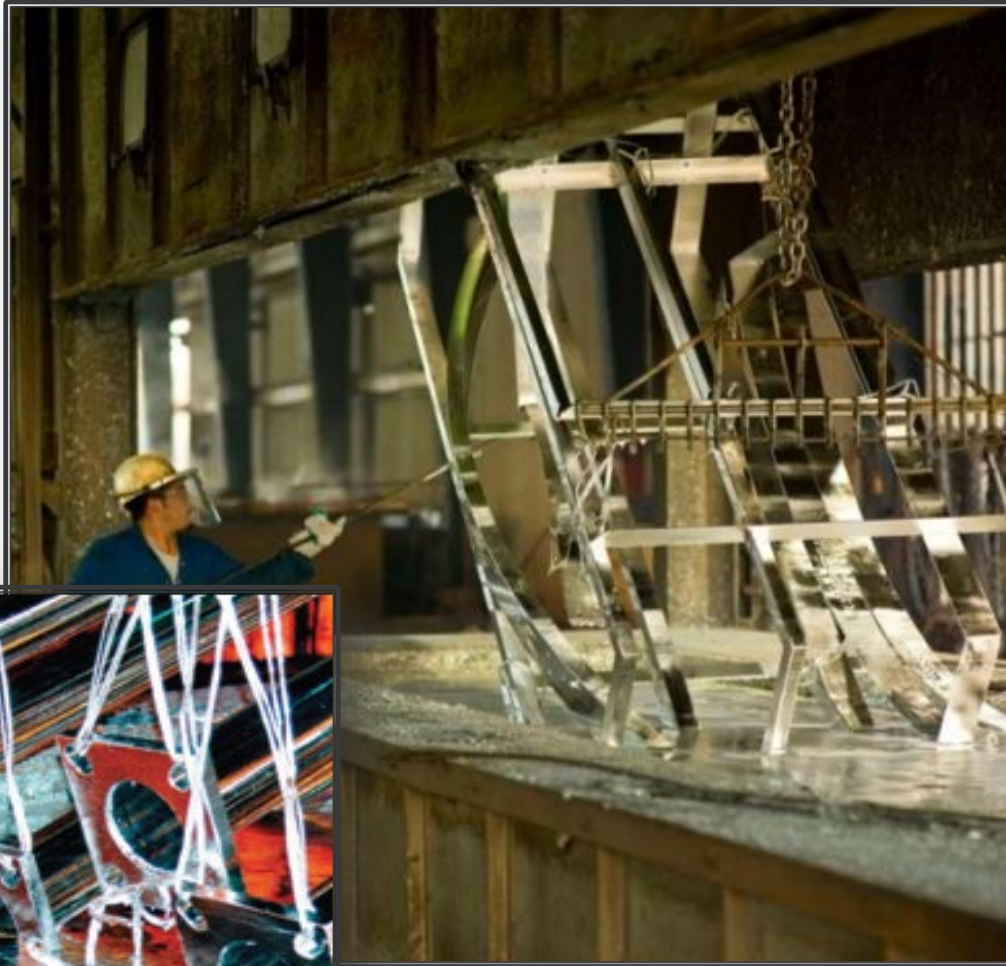
SURFACE PREPARATION

- ▶ Thorough cleaning is necessary as zinc will only react with clean steel
- ▶ Three cleaning solutions:
 - ▶ **Degreasing** – removes dirt, oils, organic residue
 - ▶ **Pickling** – removes mill scale and oxides
 - ▶ **Fluxing** – mild cleaning, protective layer
- ▶ Unclean areas will not grow zinc coating



*Galvani
ze It!*

GALVANIZING



- ▶ Steel immersed in bath (kettle) of molten zinc (~830 F)
- ▶ Bath chemistry >98% pure zinc
 - ▶ Up to 2% additives (Al, Bi, Ni)
- ▶ Molten zinc reacts with iron in steel to form metallurgically-bonded coating
- ▶ Reaction is complete when steel reaches bath temperature



HDG SPECIFICATIONS

ASTM STANDARDS

- Requirements for coating thickness, finish/appearance, and adherence
- ASTM A123
 - General iron/steel products
- ASTM A153
 - Fasteners/small parts centrifuged or spun
- ASTM A767
 - Reinforcing steel (rebar)
 - Also has bend diameters

OTHER GALVANIZING STANDARDS

- Canadian Standards Organization
 - CSA G164
- International Organization for Standardization (ISO)
 - ISO1461
- American Association of State Highway Transportation Officials (AASHTO)
 - AASHTO M111
 - AASHTO M232

SUPPORTING SPECS (PRE-GALV)

- ▶ ASTM A143
 - ▶ Safeguarding against embrittlement
- ▶ ASTM A384
 - ▶ Minimizing warpage/distortion
- ▶ ASTM A385
 - ▶ Practice for high-quality HDG coatings
- ▶ ASTM A1068
 - ▶ Life-cycle cost analysis for steel corrosion protection

SUPPORTING SPECS (POST-GALV)

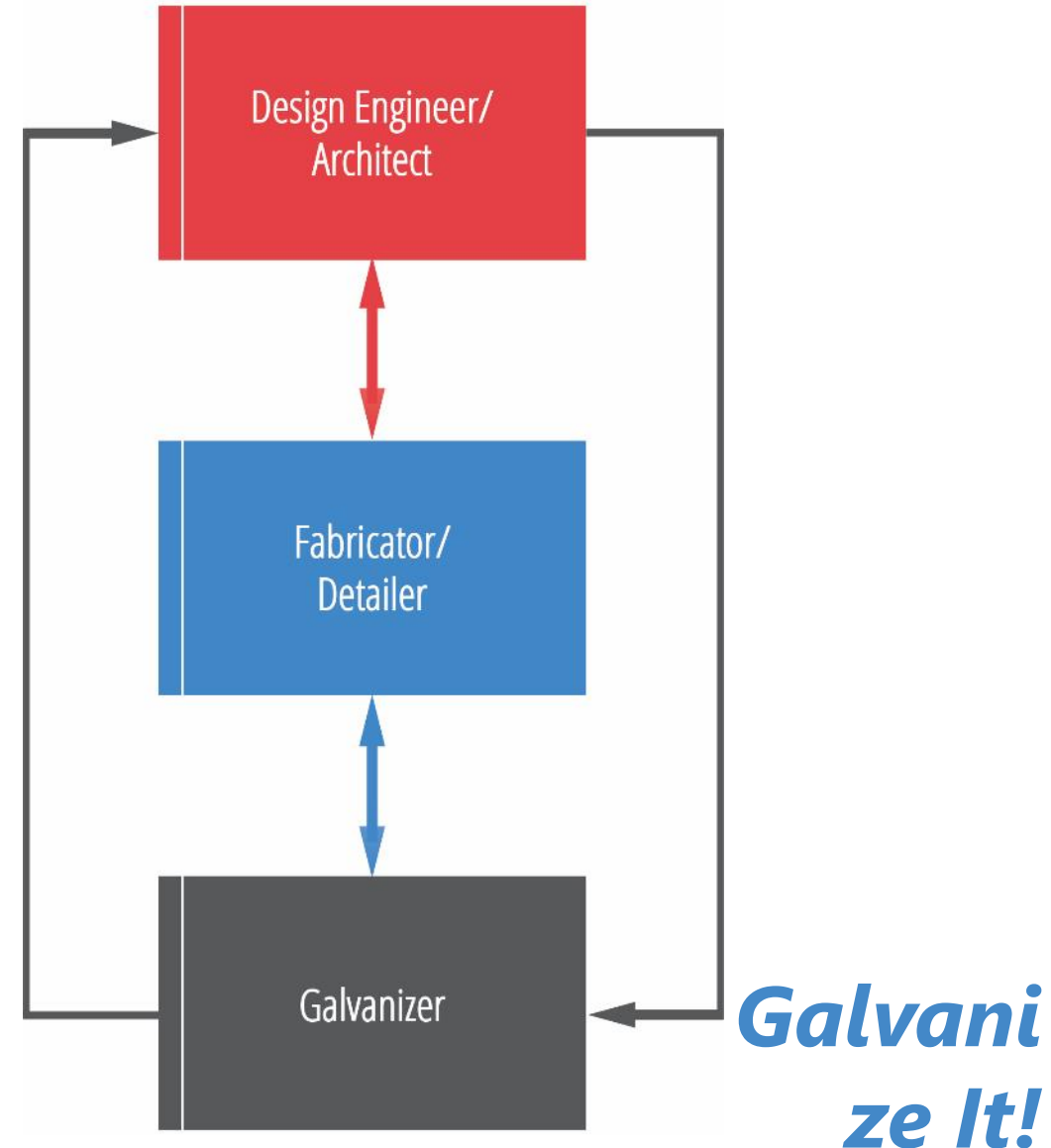
- ▶ ASTM A780
 - ▶ Touch-up and repair of galvanized products
- ▶ ASTM D6386
 - ▶ Surface preparation for painting over HDG
- ▶ ASTM D7803
 - ▶ Surface Preparation for powder coating over HDG



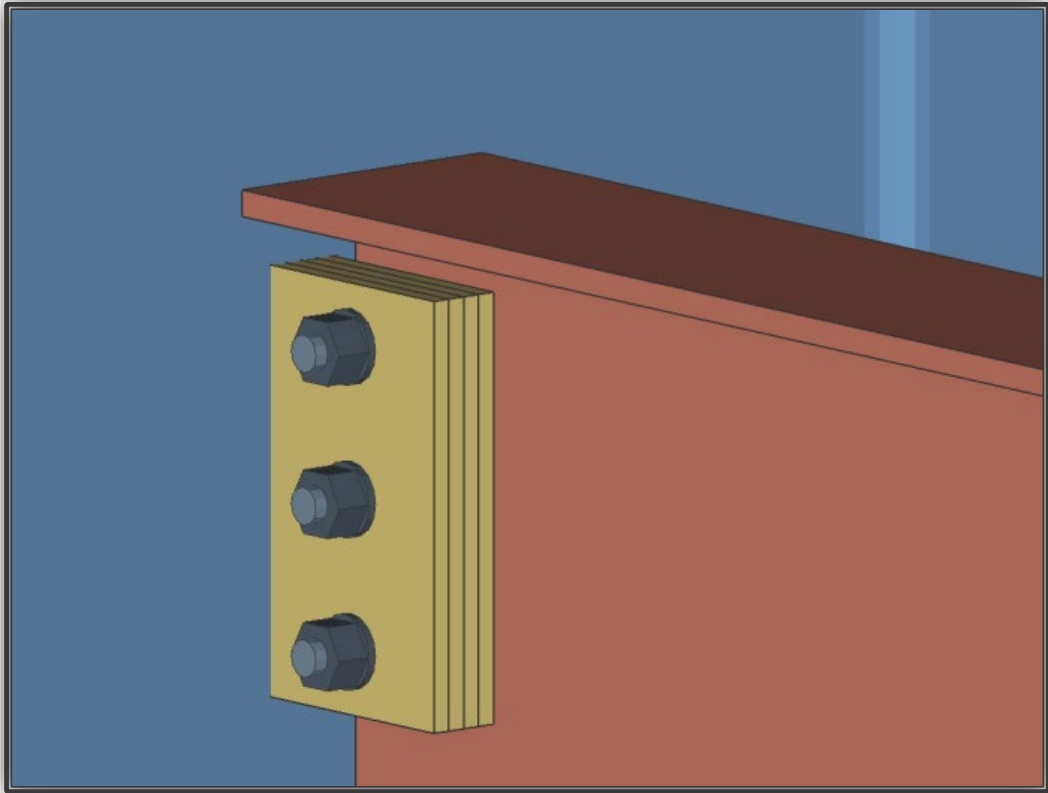
DESIGN & FABRICATION

COMMUNICATION IS KEY

- Steel Chemistry & Surface Condition
- Size & Shape
- Process Temperature/Heat
- Venting & Drainage
- Welding
- Threaded Parts/Connections
- Post Galvanizing Design/Use



DESIGN DATA DETAIL SOFTWARE



***Galvani
ze It!***

- ▶ SDS/2 has incorporated galvanizing details
 - ▶ Automated vent/drain locations and sizes
 - ▶ Designate at set up or as each member is designed
 - ▶ Checks for kettle size fit, dissimilar materials, vents/drains, welds
 - ▶ Defaults to AISC Standards
- ▶ Visit **sds2.com** for details

SUITABLE MATERIALS FOR GALVANIZING

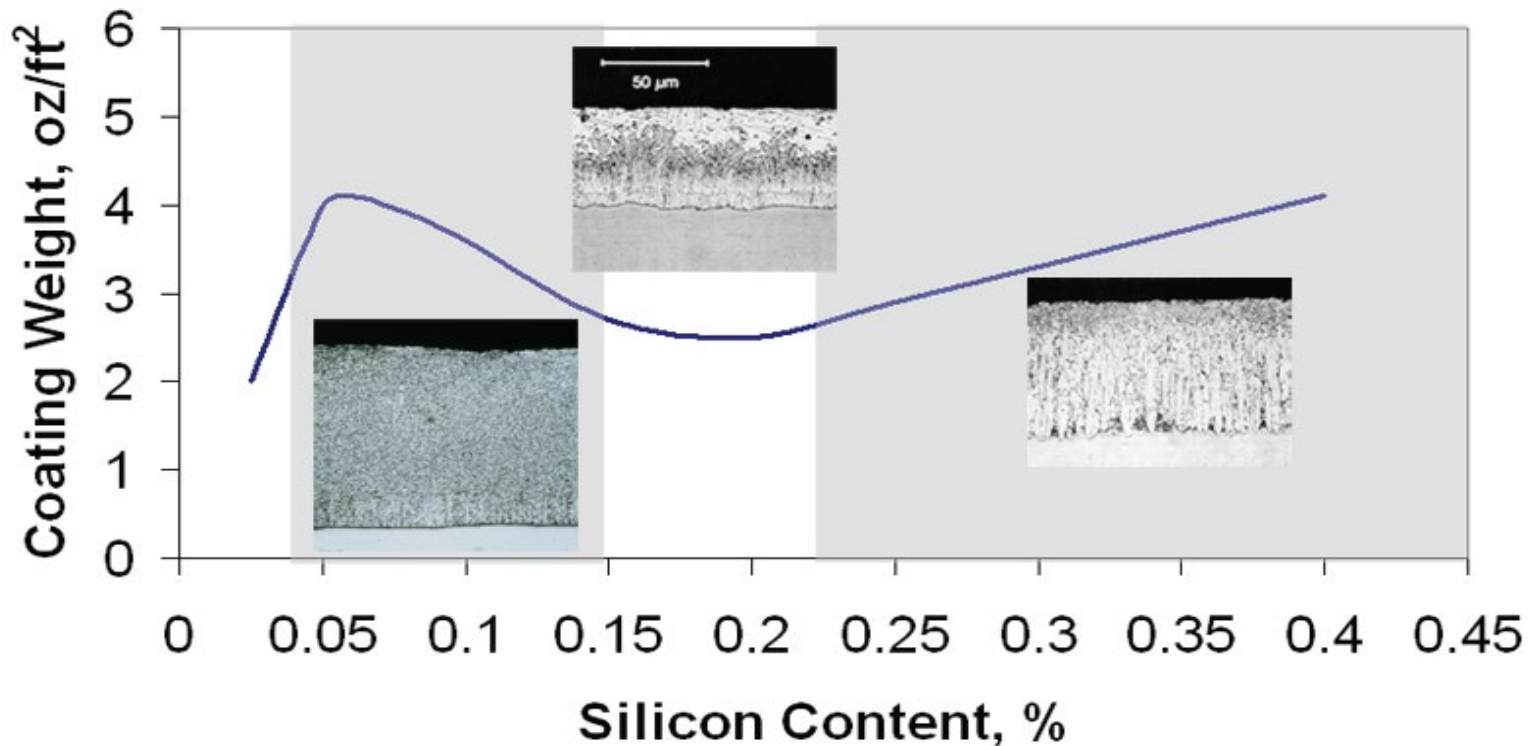


- Ferrous Metals
 - Carbon steel
 - Weathering steel
 - Stainless steel
- Fasteners
 - Centrifuged to remove excess zinc
- Castings
 - Special cleaning/design is important

***Galvani
ze It!***

STEEL CHEMISTRY

Sandelin Curve



▷ Recommended Steel Chemistry for Hot-Dip Galvanizing (ASTM A385)

- ▷ Silicon <0.04% or 0.15%-0.22%
- ▷ Phosphorous <0.04%
- ▷ Carbon <0.25%
- ▷ Manganese <1.30%

**Galvani
ze It!**

SURFACE CONDITIONS

- Varying surface conditions lead to varied appearance
 - Old/New Steel
 - Combining materials
 - Different chemistries
 - Rusted/pitted steels vs. new/machine surfaces
 - Fabrication methods
 - Process needs/time



SIZE & SHAPE



- Variety of sizes/shapes
 - Average kettle is 40 feet
 - Many kettles 50-60 feet
 - Weight can also be an important factor
- Overhead hoists/cranes move the steel
 - Chains, wires, racking systems, or perforated baskets hold materials
 - Lifting points where possible
- Design large structures in modules or sub-units and connect after galvanizing

Galvani
ze It!

PROCESS TEMPERATURE & MECHANICAL PROPERTIES

- ▶ HDG Temperature does not change
 - ▶ Steel chemistry
 - ▶ Tensile strength
 - ▶ Yield strength
 - ▶ Bend properties
 - ▶ Impact properties
 - ▶ Micro-structure
- ▶ HDG process does not “weaken” high strength steel

Galvani
ze It!



COLD-WORKING

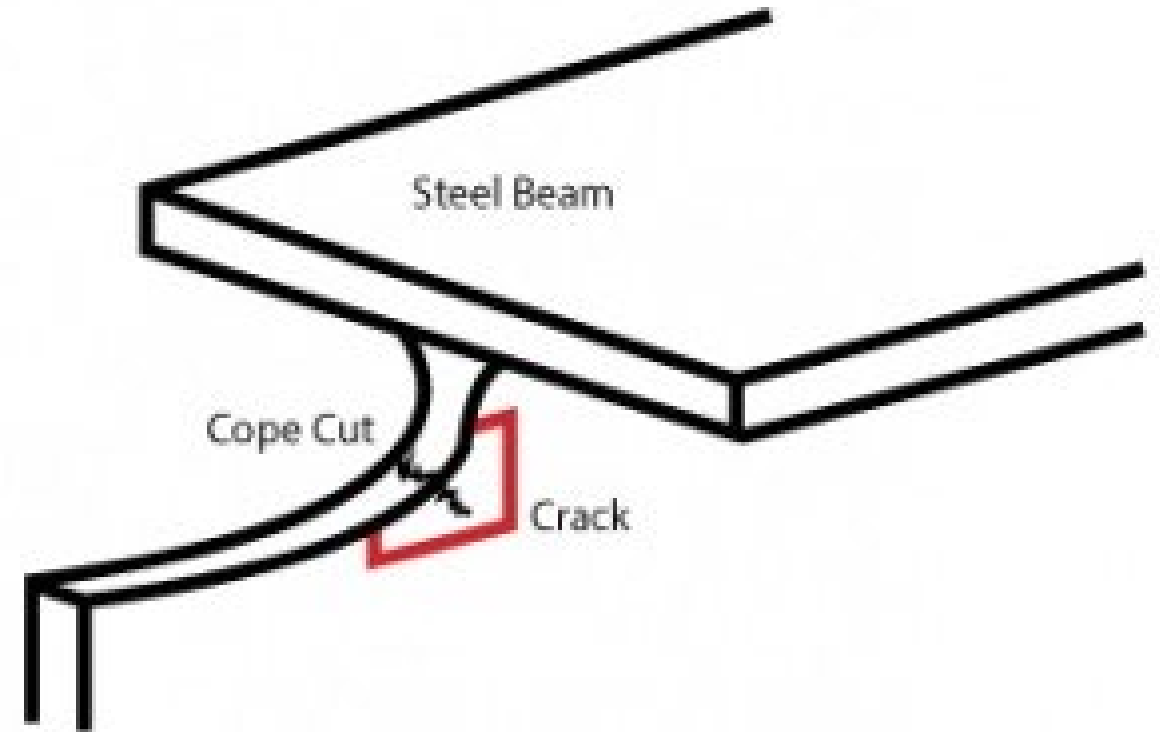


Galvanize It!

- ▶ Severe cold-working increases possibility of strain-age embrittlement
 - ▶ Heat of HDG can accelerate the affects
- ▶ Keep bend radii as large as possible before HDG
 - ▶ At least 3x the section thickness
- ▶ Refer to ASTM A143 for recommendations and stress-relieving procedures

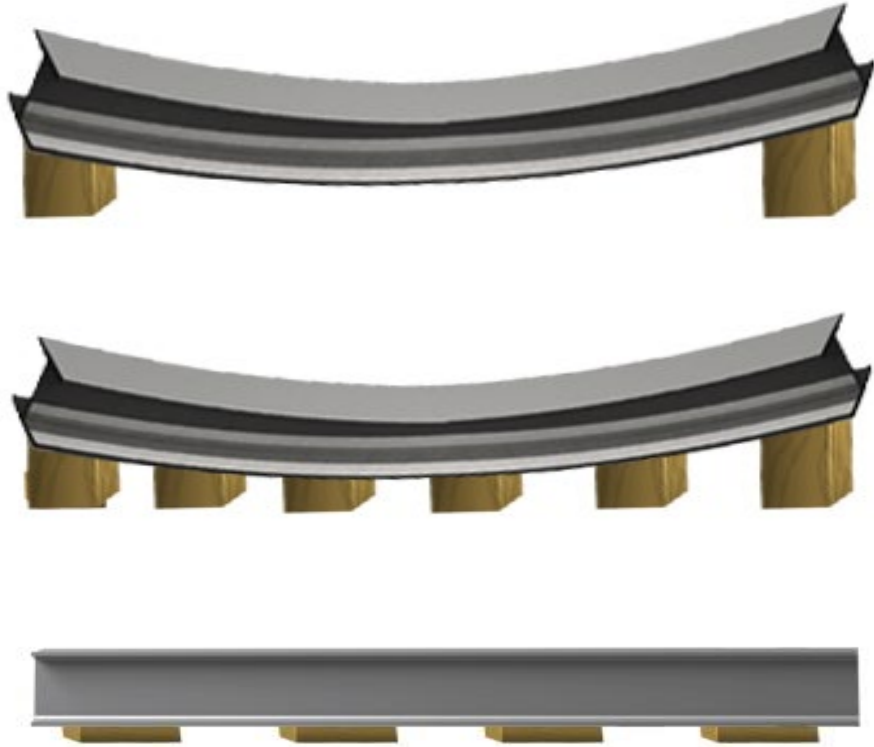
COPE CUTS

- ▶ Flame cut copes often have residual stress and rough surface
 - ▶ Can lead to cracking after HDG
- ▶ Minimizing risk for cope cracking:
 - ▶ Thermal treatment
 - ▶ Weld bead applied directly to, and extending out one inch from the cut
- ▶ Cracks can be repaired after galvanizing by welding, followed by an application of zinc per one of the methods described in ASTM A780



**Galvani
ze It!**

HEATING/COOLING RATES

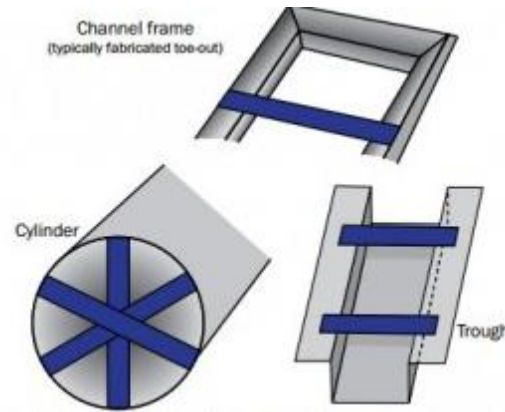
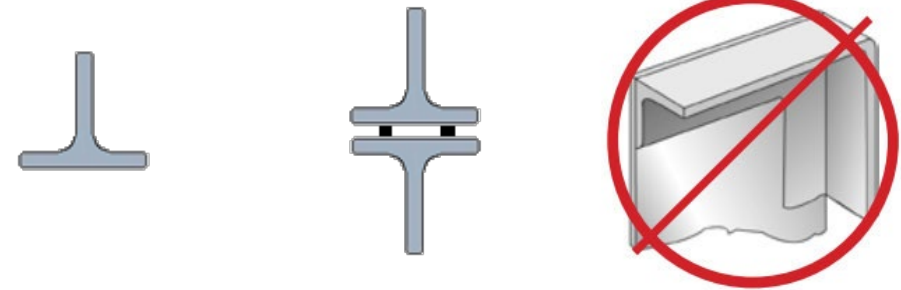


- ▶ Heat of process can relieve stresses
 - ▶ Can lead to distortion and warping of parts/assemblies
- ▶ Common design causes of Warpage/Distortion
 - ▶ Inherent stresses within steel
 - ▶ Cold working or cold rolled steel
 - ▶ Welding before hot-dip galvanizing
 - ▶ Asymmetrical design
 - ▶ Thin/thick material within assembly
 - ▶ Progressive dipping
 - ▶ Poor drainage/venting and lifting points
- ▶ Process causes (for galvanizer to control)
 - ▶ Long immersion time

**Galvani
ze It!**

BEST PRACTICES TO AVOID WARPAGE/DISTORTION

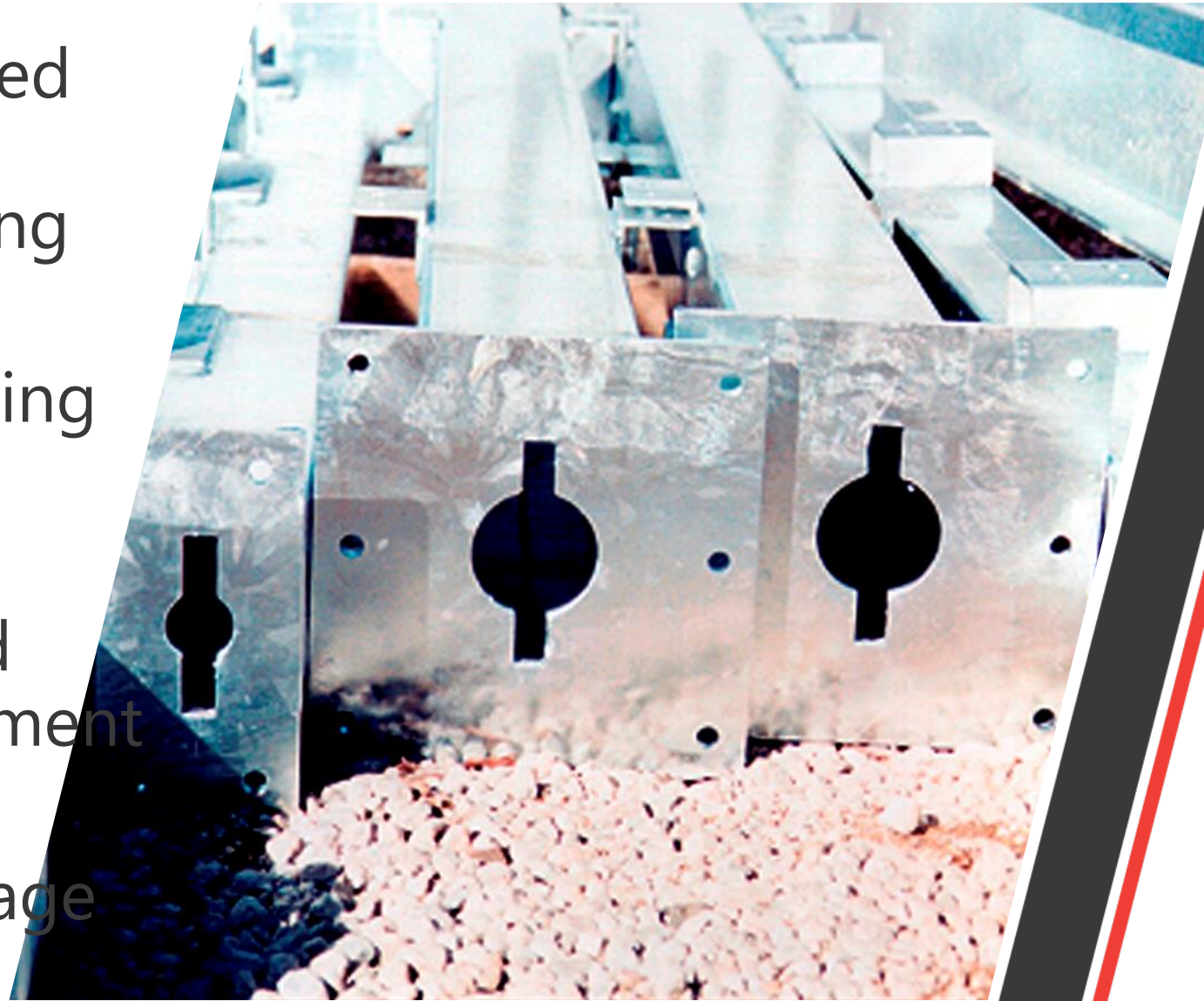
- ▶ Communication between galvanizer, designer, & fabricator early in design process
 - ▶ Follow guidelines in ASTM A384
 - ▶ Sheets/plates $\geq 1/4$ in
 - ▶ Checkered/diamond plate
 - ▶ Thermal treatment after cold working
- ▶ Symmetrical design
- ▶ Equal/near equal thickness in assemblies
- ▶ Overlapping joints
- ▶ Progressive dipping



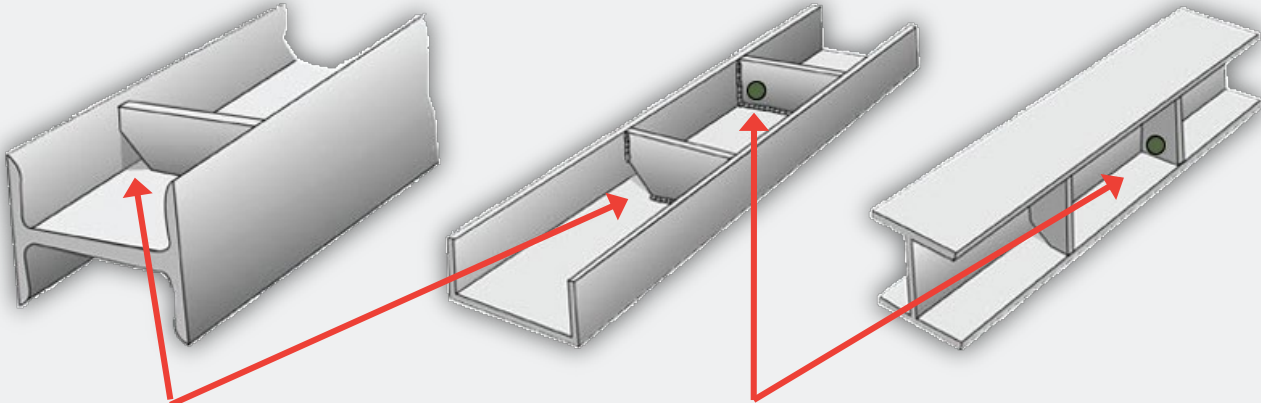
**Galvani
ze It!**

VENTING & DRAINAGE

- ▶ Cleaning solutions & zinc need to flow into, through, out of articles for effective galvanizing
- ▶ Vent/drain holes allow air to escape, immersion, and draining of excess zinc
- ▶ Extremely important for personnel safety and to avoid damage to fabrication/equipment
- ▶ Reference ASTM A385 for recommended venting/drainage designs and sizing

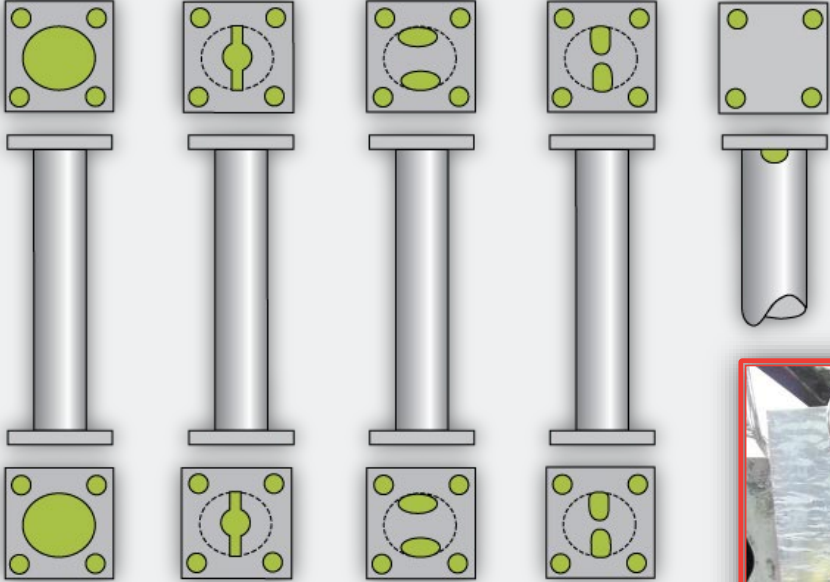


GUSSET & BASE PLATES

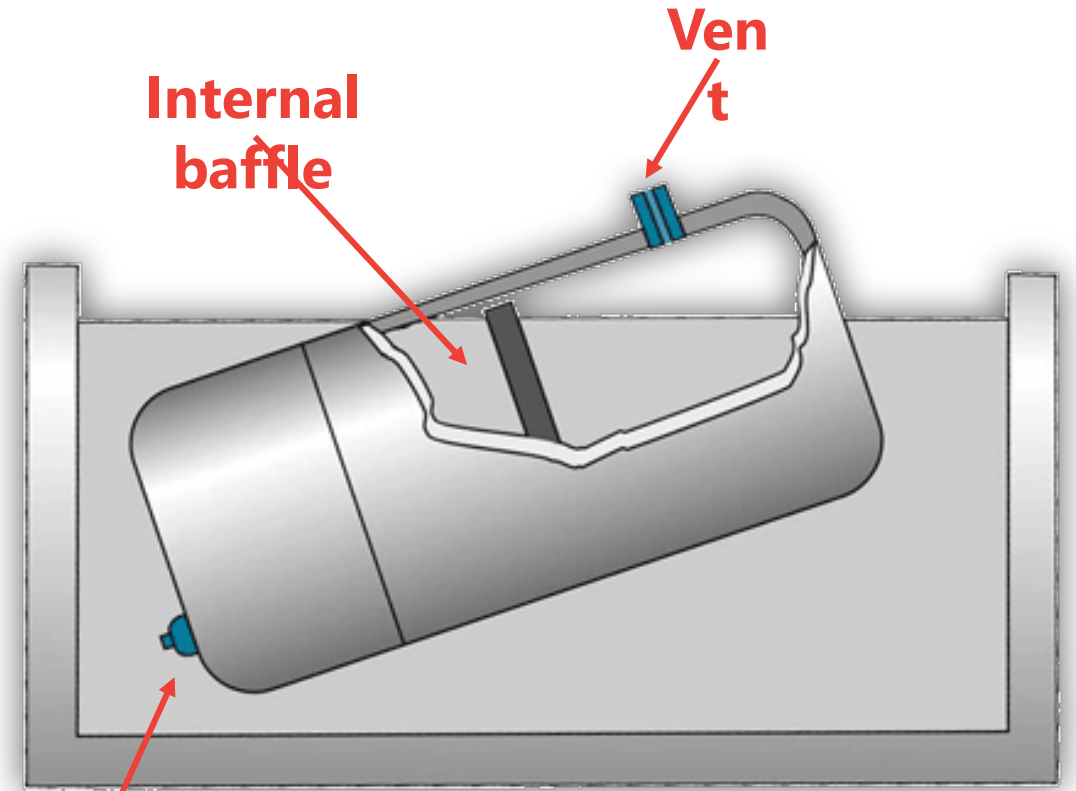
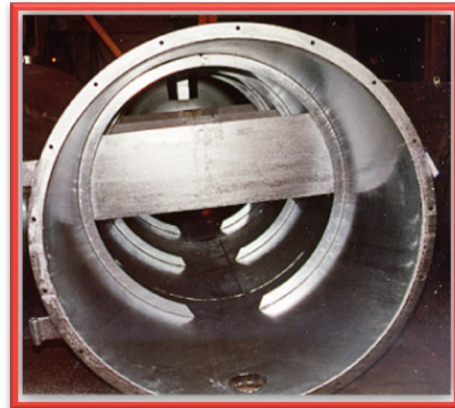
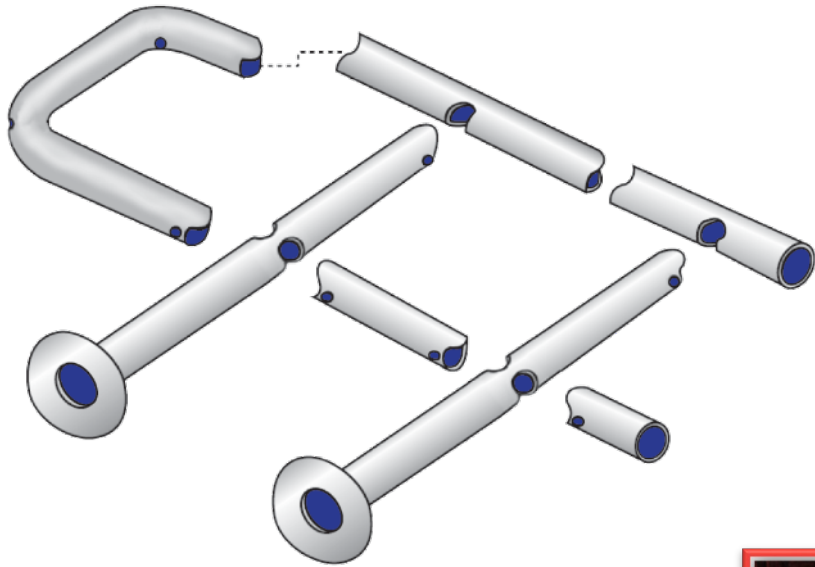


**Cropped Corners
(preferred)**

**Holes Close to
Corners
(alternatively)**



HOLLOW & ENCLOSED STRUCTURES



Drain

Internal
baffle

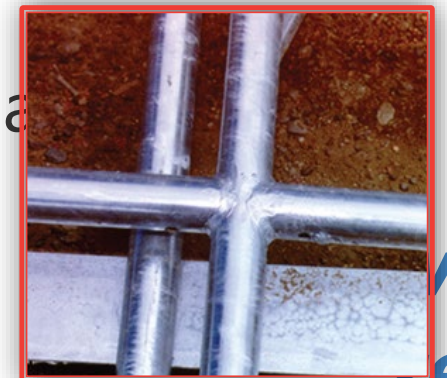
Ven
t

*Galvani
ze It!*

WELDING BEFORE GALVANIZING



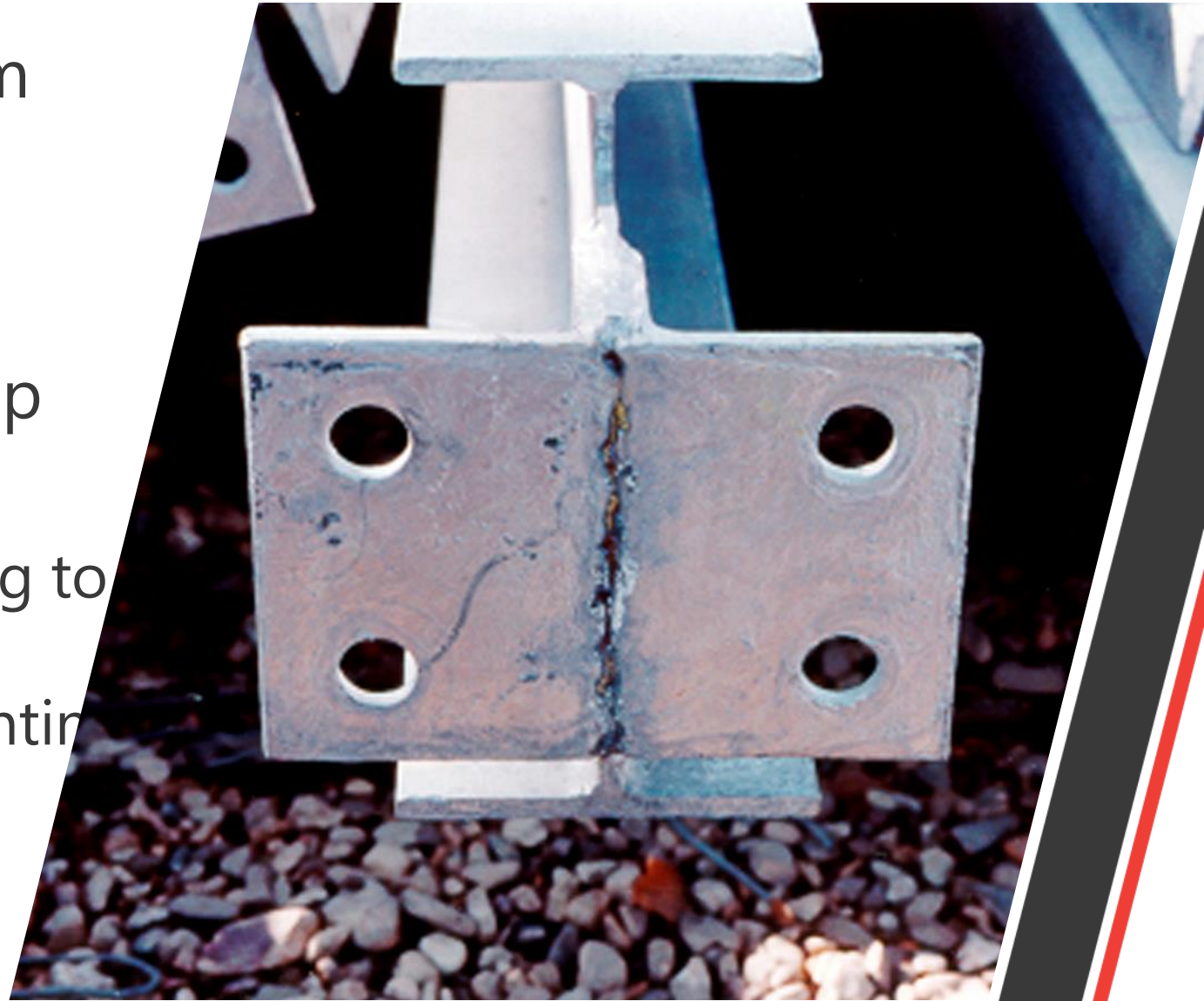
- ▶ Two items influence the quality/appearance
 - ▶ Cleanliness of the weld
 - ▶ Flux/slag must be removed by fabricator
 - ▶ Weld Rod Chemistry
 - ▶ As similar to the steel chemistry



Galvanize It!

OVERLAPPING SURFACES

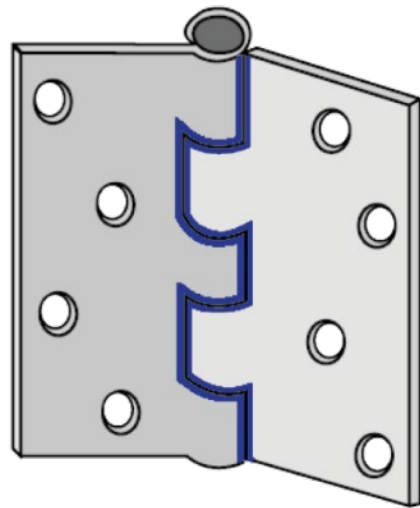
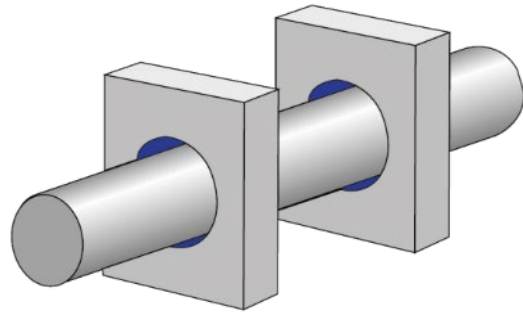
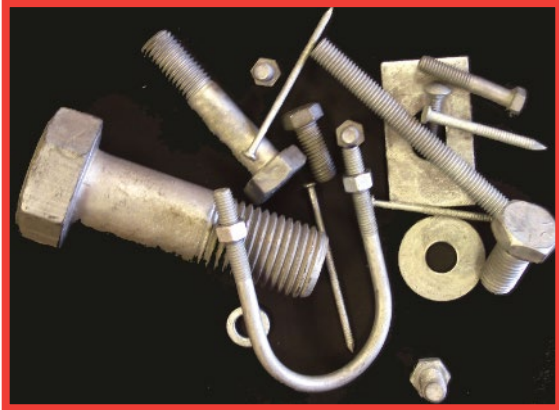
- ▶ Zinc viscosity prevents it from entering gaps less than 3/32"
 - ▶ Cleaning solutions penetrate smaller gaps – may weep out
- ▶ Stitch-Welding with 3/32" gap
- ▶ Complete Seal Welding
 - ▶ Large overlap requires venting to prevent moisture trapping
 - ▶ Reference ASTM A385 for venting requirements



VENTING OVERLAPPING SURFACES

Overlapped Area in ² (cm ²)	Steels ≤ ½ in. (12.75 mm) in Thickness		Steels > ½ in (12.75 mm) in Thickness	
	<i>Vent Holes</i>	<i>Unwelded Area</i>	<i>Vent Holes</i>	<i>Unwelded Areas</i>
under 16 (103)	None	None	None	None
16 (103) to >64 (413)	One 3/8in (1 cm)	1 in (2.5 cm)	None	None
64 (413) to >400 (2580)	One ½in (1/25 cm)	2 in (5.1 cm)	One ½ in (1.25 cm)	2 in (5.1 cm)
>400 (2580) each 400 (2580)	One ¾ in (1.91 cm)	4 in (10.2 cm)	One ¾ in (1.91 cm)	4 in (10.2 cm)

THREADED & MOVING PARTS



▸ Threaded Parts

- Zinc coating pickup makes threads thicker – affecting fit-up between male/female threads
- Overtapping of Galvanized Nuts – ASTM A563

- Zinc on male thread will protect both components

▸ Clearance Holes

- Bearing connections – no oversizing
 - Slip-critical connections – + 1/8 inch to nominal bolt diameter
 - Maximum oversizing – AISC LRFD Manual

▸ Moving Parts

- Must accommodate for zinc coating thickness

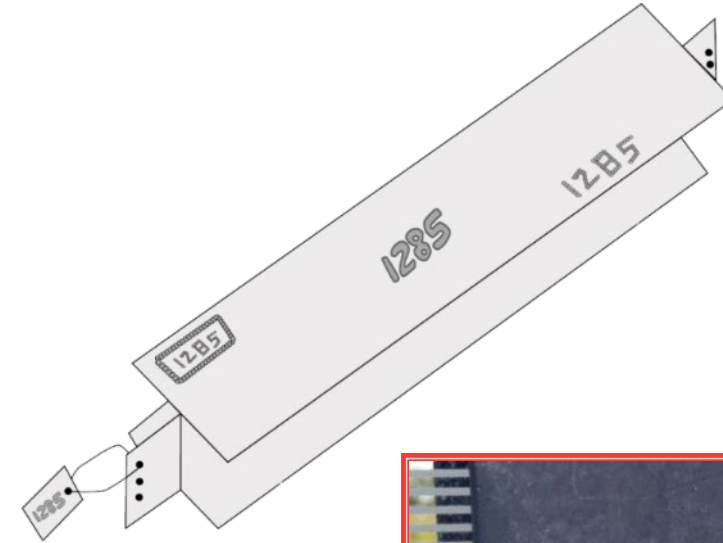
MASKING



- Treating an area of the steel to prevent coating growth
 - Threads
 - Areas to be welded
 - Studs
- Not 100% Effective
- Add significant labor in application and removal

MARKING

- ▶ Temporary
 - ▶ Metal/Barcode Tags
 - ▶ Markers
- ▶ Permanent
 - ▶ Weld Beads
 - ▶ Stamping
 - ▶ Deep Stencil
 - ▶ Refer to ASTM A385 for recommended sizing
- ▶ Oil-based markings should be avoided



**Galvani
ze It!**

HOT-DIP GALVANIZED AESS

- ▶ A123 quality often not enough to meet aesthetic requirements
 - ▶ Additional detailing required before & after HDG
 - ▶ Learn A123 requirements
- ▶ **Explicitly state responsibility for additional detailing**
- ▶ Pre-job meeting with all parties GC/Fabricator/Galvanizer critical to success
 - ▶ Use Custom Category Matrix
- ▶ AISC categorical approach
 - ▶ Optimizes cost
 - ▶ Minimizes detailing





**INSPECTION, TOUCH-UP
& REPAIR, AND STORAGE**

INSPECTING GALVANIZED STEEL



- ▶ Inspections performed/scrutinized on all HDG
 - ▶ Coating thickness
 - ▶ Finish & Appearance
- ▶ Referee Tests (only when a question arises)
 - ▶ Adherence – stout knife test
 - ▶ Run knife point along surface smoothly
 - ▶ No gouging/whittling
 - ▶ Not on edges/corners

▶ Embrittlement (ASTM A143)

***Galvani
ze It!***

COATING THICKNESS

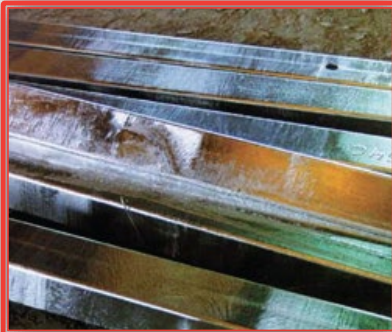
- ▶ Checked by magnetic thickness gauge
 - ▶ ASTM E376 for guidance
- ▶ ASTM A123, A153, A767 have minimum coating thickness requirements (no max)
 - ▶ Based on type of material (category) and thickness of the steel
 - ▶ Sampling requirements for inspection based on lot size & surface area of the parts
 - ▶ Information on maximum allowable area for touch-up and repair (in-plant)

FINISH & APPEARANCE

- ▶ Visual inspection with naked eye
- ▶ Some surface imperfections are allowed according to ASTM specifications
 - ▶ If they do not affect corrosion protection
 - ▶ OR intended use of product
 - ▶ Specification notes different appearances (shiny, matte, mottled) are not cause for rejection (not interfere with protection)
- ▶ Touch-up/repair is done according to ASTM A780

APPEARANCE & WEATHERING

Shiny



Matte



Spangled



**Shiny &
Dull**

Photo 12/18/02



Photo 03/28/03

TOUCH-UP & REPAIR

- ▶ ASTM A780 identifies acceptable forms
 - ▶ Zinc-based solder
 - ▶ Zinc-rich paint
 - ▶ Zinc-spray (metallizing)
- ▶ Main ASTM standards A123, A153, A767 give restrictions on size
 - ▶ Size limits only for in-plant repair
- ▶ *Touch Up & Repair* video series on YouTube



PROPER STORAGE & HANDLING



- ▶ Promote free flowing air around parts
 - ▶ During storage & shipping
 - ▶ Wood spacers to avoid nesting
 - ▶ Avoid collection of moisture
 - ▶ Stack at angles
 - ▶ Keep away from vegetation/dew
 - ▶ May want/need to cover during shipping
- ▶ Refer to AGA Publication *Wet Storage Stain* for additional info & cleaning recommendations

DESIGNING FOR HOT-DIP GALVANIZING



- ▶ Communication amongst all parties is key
- ▶ Following best design practices from the specifications leads to best quality coatings
- ▶ Inspection is simple, focusing mostly on coating appearance and thickness

Duplex systems are another area for communication and surface preparation is most important to success

**Galvani
ze It!**

AGA RESOURCES

- ▶ Galvanizer Locator/GalvaSource
 - ▶ galvanizeit.org/galvanizers
- ▶ Technical Assistance/Expertise
 - ▶ galvanizeit.org
 - ▶ aga@galvanizeit.org; 720.554.0900
- ▶ Dr. Galv KnowledgeBase
 - ▶ galvanizeit.org/knowledgebase
- ▶ AGA Project Gallery
 - ▶ galvanizeit.org/project-gallery
- ▶ *Galvanizing Insights* quarterly newsletter
- ▶ Technical Library

