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Practical Guide

Metal Duct Selection And Application

By John H. Stratton
Member ASHRAE

The most frequently used air duct material in commercial and institutional buildings is galvanized steel of commercial and lockforming qualities. The base metal may be hot-rolled or cold-rolled steel, it usually has a carbon content of not more than 0.15%, and it may be capped, rimmed or semikilled type. Type refers to control of gas evolution during solidification and affects surface characteristics and uniformity of chemical composition.

Chemical and metallurgical properties and applications of steels can be found in the Steel Products Manuals and the AISI Standard Steels Handbook available from the Iron and Steel Society, www.issource.org. The products manuals describe and illustrate imperfections such as coil breaks, edge breaks and fluting. The handbook has heat range limits and unified numbering systems (UNS).

Hot-rolled steel typically begins as a slab from an open hearth, basic oxygen, or electric furnace process. The slab is rolled, finished, and cooled in a continuous process. To make cold-rolled sheet, hot-rolled coils are pickled in acid, water rinsed, dried, cold reduced, annealed, and then temper-rolled for hardness, flatness, and surface quality. Cold rolling can produce a thinner and smoother product than can be made in a hot mill. The steel-making process can be reviewed on the web site of the American Iron and Steel Institute, www.steel.org.

The continuous hot-dip galvanizing process involves electrolytic cleaning for better zinc adherence, brush scrubbing, radiant heat annealing, submergence in a pot of 99% pure zinc, chemical treatment to prevent surface staining, roller stretch flattening, then recoiling for shipment.

In 1994, ASTM combined several standards on steel sheet, metallic-coated by the hot-dip process into two new "standard" specifications. A 924, general requirements, covers chemical tolerances, tests for mechanical properties, tests for coating properties, and tolerances for thickness, width, length for cut sheet, camber, squaring, and flatness (for cut lengths). A companion specification, A 653, covers terminology on alloys and coating designations, coating weights, quality classifications (including structural and high-strength, low alloy), heat analysis, bending properties, and ordering variables. Conversions for coating weight to thickness in mils also are provided.

ASTM A 924 and A 653 cover the following metallic coatings: zinc, zinc-iron alloy, zinc with 5% aluminum alloy, 55% aluminum-zinc alloy, aluminum, and lead-tin alloy (terne). Separate ASTM specifications for several of these are still maintained. However, the familiar A 525 (general requirements), A 526 (commercial grade), and A 527 (lockforming quality) that still appear in some outdated codes and project specifications, have been abandoned. ASTM A 924 and A 653 are the appropriate current references.

The following commentary on materials produced to ASTM A 924 and A 653 may be useful:

- The outdoor life expectancy of zinc coating is deemed linear in relation to thickness. Rates have been studied extensively in rural, tropical marine, temperate marine, suburban moderate industrial, and heavy industrial environments. Years to first rust for G 90 coating outdoors average three to seven for severe industrial, 15 to 20 for rural, seven to 10 for Atlantic coast marine, 12 for suburban, and 10 for urban.
- The service life of zinc in dry indoor conditions has not been studied formally. Without condensation, high humidity, chemical exposure, or major temperature changes, the small amount of corrosion that occurs causes only discoloration in 20 to 30 years. More corrosion is predictable in wet and wet-dry cycle conditions. G 60 and even G 90 galvanized coated steels are not considered appropriate choices for indoor chlorinated pool areas.
- Sheet produced with regular spangle finish exhibits the multifaceted zinc crystals familiar on galvanized ductwork. These large crystals result from unrestricted growth of zinc crystals during solidification. Minimized spangle has

About the Author

John H. Stratton is a mechanical engineer, director of technical services for SMACNA for 30 years, and active with T.C. 5.2, Duct Design, as a member or corresponding member for more than 25 years.

a dull, non-uniform appearance. It is not often used for ductwork.

• Zinc-iron alloy, also called galvannealed, is a dull gray, non-spangled coating that is used as a pre-treatment for shop or field painting. It is not suitable for prepainting on a coil coating line.

• ASTM D 2092 covers practices for preparing zinc-coated galvanized steel surfaces for paint, including phosphatizing. Exposed ducts in large spaces like shopping centers and airports are often painted.

• ASTM A 653 classifies zinc coatings from G 01 to G 360 and zinc-iron alloy coatings as A 01, A 25, A 40, and A 60. Metrics units use Z coating classes for zinc. Air ducts normally have G 60 or G 90 zinc coating. The G number is the amount of zinc per square foot of sheet. It refers to the total weight of coating on both sides of the sheet in hundredths of an ounce. G 90 sheet has a total of 0.90 oz (26 g) of zinc per square foot of sheet. The average nominal coating thickness is 0.76 mils per side.

By ASTM standards, G 90 may have a coating thickness as low as 0.54 mils on one side. For G 60, the coating would be five-eighths of G 90 or 0.34 mils minimum per side. G 60 is used commonly for dry indoor ducts. G 90 minimum should be used in any outdoor exposure or wet indoor application. The laboratory test standard for coating mass is ASTM A 90.

• The comparable International Standards Organization (ISO) document for continuous hot-dip zinc-coated carbon steel sheet of commercial, lockforming quality is ISO 3575.

• Lockforming quality is necessary to form seams such as the Pittsburgh lock at high speed. The Pittsburgh lock has two tight 180° bends. With lockforming quality sheet, neither the zinc coating nor the base metal should crack or flake on the outside of the bend, although ASTM standards permit flaking within one-quarter inch of an edge. Bends can be tested with the axis of fold parallel to and perpendicular to grain.

• Galvanized steel normally has a thin oil coating to inhibit wet storage stain or "white rust." If moisture remains between cut sheets, coil wraps or nested storage items, staining can result. Minimal stain should not impair coating effectiveness indoors. It can be removed with household bleach. Significant staining indicates inadequate protection. In some cases exposure to chemical fumes will cause a similar appearance.

• Structural steels (with mechanical properties related to ASTM A 446) are not used for HVAC ducts. They have a minimum yield strength (F_y) of 33,000 psi (227 600 kPa) and a minimum tensile strength of 45,000 psi (310 360 kPa). SMACNA's HVAC duct standards are based on 30,000 psi (206 900 kPa) minimum yield strength. The nominal allowable stress for light gage cold-formed steel per AISI specifications is 0.6 F_y, with reductions for width-to-thickness ratios when necessary to analyze the section for buckling. Mechanical engineering and structural engineering handbooks use similar criteria.

• ASTM A 792 governs the nominal 55% Al-Zn alloy coated steel known by such names as "Galvalume" and "Zincalume." Its actual composition is 55% aluminum, 43.5% zinc and 1.5% silicon. It is two to four times as corrosion resistant as G 90 coated steel in outdoor marine, rural, and industrial environments. Predominant uses are in metal buildings and structural roofing. It might be used for outdoor ducts, but SMACNA contractors found its greater hardness, strength, and drill resistance awkward to cope with when used for ductwork.

• Electro-galvanized cold-rolled steel sheets have a thin coating of zinc applied by electrolytic deposition. The ASTM standard is A 591. The coating, normally about 0.08 mils, has a uniform dull gray matte appearance without spangle. It is typically phosphate treated for paint adherence and should be painted after removing the protective oil coating. Outdoor use is not recommended even if painted. Some fire damper manufacturers have used the coating to obtain UL 555 listing. Warehouse stock sizes are limited.

• Aluminized (aluminum-coated) steel, covered in ASTM A 463, is available in Types 1 and 2. Type 1, with a coating of 92% aluminum and 8% silicon, is used for elevated temperatures in vents rated under NFPA Standard 211, heat exchangers, and some industrial process ducts that operate up to 900°F or 1000°F (482°C to 538°C). Discoloration occurs over 900°F (482°C). Care must be taken to avoid marring the soft coating. 180° bends should not have less than one metal thickness radius. Type 2 is used for roofing, siding, and storm drainage pipe.

• Polyvinyl chloride (PVC)-coated steel ducts are used for fume exhaust, underslab, and underground ducts. The PVC coating might be applied on one or both sides of the duct, interior or exterior, in about 4 mil thickness. One mil coating is often used on the interior of underground ducts. G 60 coated galvanized steel is used with supplemental coatings added before the final plastic coating(s). Materials so coated can pass UL 723 and UL 181 flame spread of 25 maximum and smoke developed of 50 maximum. Even so, local (and model) mechanical codes usually make use of PVC-coated duct subject to approval of the Authority Having Jurisdiction (AHJ).

The approval process is facilitated by Evaluation Reports (ER) issued by the National Evaluation Service (NES) or by an individual model code writing agency Evaluation Service (ES). Producers pay to get and maintain such recognition. ICBO publishes a comprehensive set of Acceptance Criteria (AC). An applicant must satisfy those criteria for its products or systems to qualify under the Alternate Materials and Methods provisions of the ICBO codes. The Acceptance Criteria give AHJs a uniform, defined basis for allowing alternates without having to exercise much independent judgement. PVC ducts and fiber-reinforced (FRP) ducts have been approved based on the evaluation reports. PVC-coated steel ducts are available in rectangular shape. Most round shapes are spiral seam formed. The manufacturer's installation instructions should be followed carefully. They often prescribe a maximum service temperature of 150°F to 200°F (65°C to 93°C).

• The service temperature limit of NFPA 90A HVAC ducts is 250°F (121°C). Hot-rolled and cold-rolled steel has a 650°F (343°C) limit for industrial use without stress reduction. Zinc

Project Specifications, Codes And Standards Review Issues

1. Jobsite Inspections

Codes and duct construction standards do a fairly good job of defining materials application and use. However, lack of adequate compliance inspections leaves the highly competitive plan-and-specification bid process vulnerable to unaccounted for substitutions and oversights, both intentional and unintentional. Without inspections, full compliance cannot be expected. The "commissioning" process might assist in improving systems operation but it is no substitute for construction inspections.

2. Project Specifications

All too often, project specifications are not updated for codes and standards as they should apply for the specific project. Exculpatory clauses that say in sweeping fashion "provide all materials and devices required by the mechanical code" and "comply with the latest edition of the SMACNA standards" indicate that the designer did not coordinate his specifications with specific editions. It does not take long to discover, for example, that the SMACNA HVAC-DCS uses G 60 coated galvanized steel sheet, that reinforcements may be uncoated steel, and that overhead hanger attachments are a performance specification (that may need some supplemental specifications to coordinate with allowable floor deck load conditions or acceptable attachment methods).

3. Design Drawings

Even though computer-generated drawings enhance the ability to coordinate trades so multiple systems fit in the space available, interferences in ceiling cavities have not declined. Some designers *size* duct systems but don't *design* them. Fans are sometimes not adequately matched to duct system losses, and duct construction pressure classes are not clearly designated, leading to speculation during bidding.

coated steels have a 400°F (204°C) service limit.

• Welding processes, procedures, practices, specifications, and certifications are covered in the AWS D 9.1, Code for Welding Sheet Metal, the multiple Welding Procedure Specifications (WPS) of AWS, and the SMACNA Managers' Guide to Welding. These specifications cover steels, galvanized steels, stainless steels, and aluminum in all common welding processes.

• The ASM International's Handbook of Corrosion Resistance is an especially useful text for chemical resistance and atmospheric corrosion. It contains data from many sources. This book covers carbon steel, zinc, stainless steel, aluminum, titanium, and many other metals. Visit www.asm-intl.org.

Stainless Steel

The most frequently used grades of stainless steel for ductwork are Types 304 and 316, with 2B finish. Types 304L and 316L have lower carbon content for better welding. 2D finish is used where appearance is of no concern. Common commercial uses are dishwasher or other kitchen exhaust and laboratory fume exhaust. Type 316 is used for kitchen hoods and, for ex-

ample, perchloric acid hoods. Portable test kits have long been available for identifying the grade of stainless steel, as well as for low carbon steel, aluminum, and many other alloys.

SMACNA's HVAC-Duct Construction Standards permit substituting stainless steel for galvanized steel duct on the basis of equivalent base metal thickness. The just published second edition of the SMACNA Round Industrial Duct Construction Standards contains construction schedules for stainless steel in the negative 30 in. w.g. to positive 50 in. w.g. (–7464 Pa to 12 440 Pa) pressure range, for diameters to 96 in. (244 cm). The maximum service temperature is 800°F (427°C). Design formulas and criteria in the standard permit custom design for other conditions.

Stainless steel has a modulus of elasticity of 28 million psi compared to 29.5 million for carbon steel. The yield strength is 40,000 to 42,000 psi (275 800 to 289 590 kPa). Tensile strength is 75,000 to 80,000 psi (517 125 to 551 600 kPa). Compared to carbon steel, stainless steel can handle more stress but will have about 4% more deflection because of the lower modulus.

ASTM A 480 gives general requirements for stainless steel sheet. ASTM A 276 gives properties of the 300 series alloys. Hot-rolled angles and channels should conform to ASTM A 276. Structural sheet, plate and flat bar are in ASTM A 666. Design criteria for cold-formed structural members are in ANSI/ASCE 8.

Complementary publications that competently cover the properties, finishes, fabrication, fastening, specifications, end uses, suppliers, and care and cleaning of stainless steels are available from the Specialty Steel Industry of North America (SSINA) and the Nickel Development Institute (NIDI). Visit www.ssina.com and www.nidi.org.

Aluminum

Aluminum ductwork is normally 3003 alloy H 14 temper per ASTM B 209 with dimensional tolerances of ANSI Standard H 35.2. "Utility grade" or 1100 alloy aluminum is not equal to 3003.

With a 10 million psi modulus of elasticity, 21 ksi (145 MPa) yield strength, and an ultimate strength of 22 ksi (152 MPa), aluminum has never been recommended for rectangular duct at 4 in. w.g. (995 Pa) or higher. Some people still falsely believe that aluminum duct wall can simply be two Brown and Sharpe gages heavier than galvanized sheet gage for equivalent performance. That rule of thumb was published in the ASHRAE Handbook in the 1950s and still appears in some model and local codes. It is not valid. Below 20 gage, a 2 gage increase amounts to only 0.001 to 0.002 in. increase in thickness. Because of its low modulus of elasticity, aluminum requires a 44% increase in thickness to match the deflection performance of galvanized steel.

Angle reinforcements for aluminum duct are normally 6061 alloy T6 temper per SMACNA's HVAC-DCS (for rectangular ducts for 3 in. w.g. or less) and SMACNA's Round Industrial DCS (for non-abrasive applications at pressures from negative 30 to positive 50 in. w.g. (–7464 Pa to 12 440 Pa) in diameters up to 96 in. [244 cm]). Tables in the industrial manual are for 250°F (121°C) service but procedures in the manual allow for calculations at temperatures up to 400°F (204°C).

A typical use of aluminum is for indoor swimming pool exhaust. Although corrosion tables show some corrosion at moderate concentrations of chlorine, the aluminum industry is quick

to point out that aluminum ladders and diving board supports are common in pools. NIDI has a booklet on using stainless steel in pool areas that can be consulted for comparison. Handbook tables show some corrosion of stainless steel in chlorinated water also. Successful use of aluminum appears to relate to unknown, probably low, concentrations of chlorine in exhaust air, limiting condensation in exhaust ducts, and making ducts drain.

Galvanized steel angles can be used for external reinforcements on aluminum ducts when electrolyte (water) will not collect between the contact surfaces. Because of the mass ratio, galvanic corrosion does not occur in dry conditions. Several cases of severe galvanic corrosion have occurred when a section of aluminum duct was connected to galvanized steel without an isolating medium. The safe approach is to paint the contact surfaces with a coating such as zinc chromate primer (Federal Spec. TT-P-645) or other coating that will prevent moisture entrance. If aluminum will be in contact with uncoated carbon steel, the Aluminum Association recommends a follow-up coat containing 2 lbs (0.9 kg) of aluminum paste pigment per gallon over the primed steel.

Regarding painting, the Society for Protective Coatings, formerly known as the Steel Structures Painting Council, has extensive prescriptions for cleaning, priming, finishing, and restoring. The Architectural Aluminum Manufacturers Association has less voluminous specifications but provides useful data for coatings, sealants, joining of dissimilar metals.

SMACNA's rectangular duct schedules include instructions for adapting the steel tables (by thickness and dimension) for aluminum at 3 in. w.g. (746 Pa) pressure class or less. The infrequent use did not justify the expense of developing new tables by testing.

Copper

Cold-rolled copper ducts are rarely used. Occasionally they are used for aesthetic effect in restaurants, with hoods in lobbies or atria (often more ornamental than functional) and in other special effects scenarios. The copper duct table that was in the 1950s ASHRAE Guide Book still appears in the ICBO Mechanical Code. In that table, 16 oz/ft^2 copper is used up to 12 in. width, 24 oz. from 13 in. to 30 in., and 32 oz. and 36 oz. in larger widths. These schedules could be considered for 0.5 in. w.g. (124 Pa) service and with modification for 1 in.w.g. (249 Pa) duty.

Conclusion

Market forces seem to inhibit commitment to attentive duct system design despite a wealth of available materials science, design databases and application information. These resources include SMACNA construction standards, the specifications of other associations and the ever-growing Fitting Loss Coefficient Database of ASHRAE. ■