7. Current Challenges in Continuous Sheet Galvanizing -Process and Products	
GalvInfoNote 7.1	**Annealing Temperature Control and the Effect of Surface Emissivity on AHSS Production in Continuous Galvanizing Lines** **Rev. 0.1 | 1 September 2026**

Purpose of this GalvInfoNote

This note is intended for continuous galvanizing line operators, process engineers, furnace specialists, quality engineers and product-development personnel. It explains why accurate strip temperature control is unusually important for advanced high strength steels (AHSS), how surface emissivity affects both radiative heating and pyrometric temperature measurement, how annealing atmosphere and selective oxidation interact with emissivity, and how production teams can diagnose and reduce temperature-related process variation. The note is technology-neutral and does not endorse a particular pyrometer, furnace design or control supplier.

The central production message is simple: the furnace recipe does not heat a chemistry in the abstract; it heats a moving strip whose gauge, speed, surface roughness, oxide state and spectral emissivity can change from coil to coil and during the thermal cycle. AHSS mechanical properties and galvanizability depend on the actual temperature-time history of the strip. A pyrometer only infers that history from radiation, and the inference is only as good as the treatment of emissivity and reflected background radiation [1-8].

For conventional low-alloy products, a modest temperature deviation may be tolerated within a broad process window. For DP, TRIP, complex-phase and third-generation AHSS, relatively small thermal excursions can alter austenite fraction, recrystallization, carbon and manganese partitioning, retained-austenite stability, martensite fraction and surface selective oxidation. The resulting product can meet coating appearance requirements yet miss mechanical-property targets, or meet strength targets while showing poor Zn wetting, bare spots or unstable coating behavior [2,16-19].

1. Temperature Control in the CGL: Control the Strip, Not Only the Furnace

A modern continuous galvanizing line (CGL) normally combines cleaning, preheating/heating, soaking, controlled cooling, zinc-bath entry and post-coating operations in one continuous process. Depending on the line design, heating may use direct-fired sections, radiant-tube sections, electrical heating, or combinations of these. AHSS-capable lines may additionally employ rapid jet cooling, overaging/equalization sections and atmosphere control by furnace zone [1,9-11].

From a production standpoint, the important controlled variable is the strip temperature trajectory. Furnace wall temperature, radiant-tube temperature, burner firing rate and gas temperature are manipulated variables or intermediate measurements. They are not substitutes for strip temperature. A change in strip thickness, line speed, entry temperature, steel heat capacity, surface radiation properties or furnace loading can change the strip thermal response even if furnace setpoints remain unchanged [9-11].

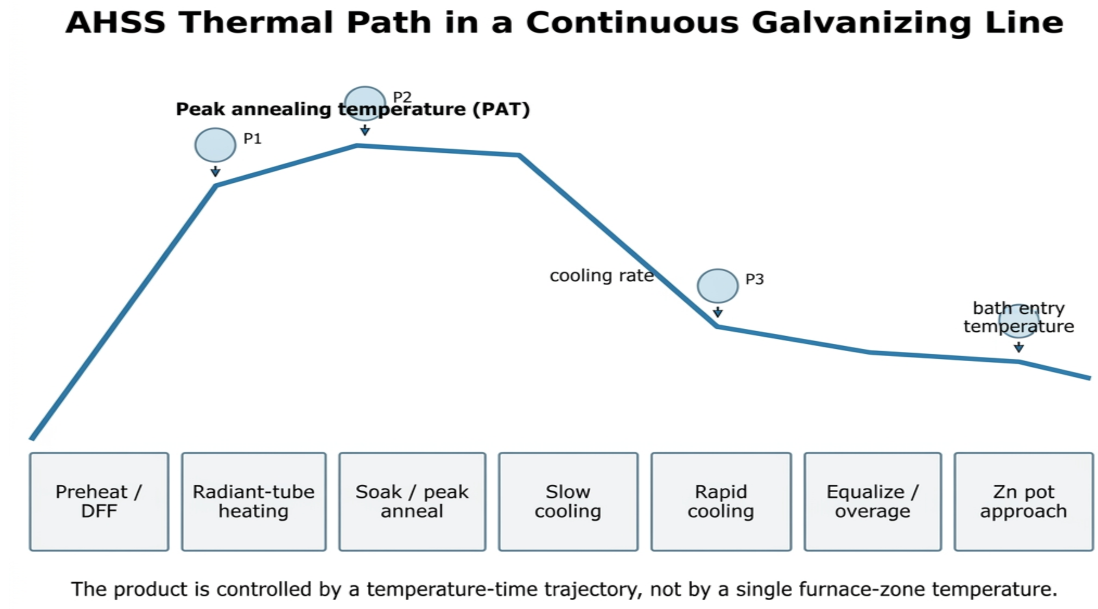

Figure 1. Simplified AHSS thermal path through the annealing portion of a CGL. The precise configuration varies by line and steel grade. The product is defined by the temperature-time trajectory, cooling history and atmosphere, not by one furnace setpoint [1,9-11].

Production rule

Treat peak annealing temperature (PAT), soak time, cooling rate and bath-entry temperature as one linked recipe. If line speed changes, the residence time in every furnace section changes. If gauge changes, strip thermal inertia changes. A controller that corrects only the final pyrometer can still produce a different upstream thermal history.

2. Why AHSS Is More Sensitive to Annealing Temperature

AHSS obtains strength and ductility from deliberately engineered multiphase microstructures. Continuous annealing must therefore accomplish several metallurgical tasks within short industrial residence times: recovery and recrystallization of the cold-rolled ferrite, formation of austenite during intercritical or higher-temperature annealing, redistribution of carbon and substitutional alloying elements, and transformation of austenite during subsequent cooling. The relative importance of these mechanisms depends on steel family [16-19].

For dual-phase (DP) steels, the intercritical annealing temperature influences the fraction of austenite present before cooling and therefore the final martensite fraction. Increasing annealing temperature generally increases the austenite fraction over the relevant intercritical range, but the resulting strength-ductility balance also depends on ferrite recrystallization, austenite chemistry, cooling rate, martensite hardness and morphology. The target is not simply the highest possible annealing temperature [17].

For TRIP-assisted, dual-phase, and third-generation steels, temperature control is often even more critical because retained austenite volume fraction and stability depend on phase fraction and solute partitioning, adding to the tendency of forming external selective oxidation on these steels can also compromise temperature control. In one CGL-compatible medium-Mn study, changing the peak intercritical annealing temperature between 665, 710 and 740 degrees C substantially changed retained-austenite stability and the contribution of TRIP/TWIP mechanisms to deformation [18]. These values are research examples, not universal production recipes.

A key operational implication is that two coils with the same measured PAT (Peak Annealing Temperature)can still develop different properties if heating rate, time above critical temperatures, soak duration, or cooling trajectory differ. This is why robust CGL control increasingly combines strip-temperature measurements with a dynamic thermal model and coil-specific feed-forward variables [9-11].

AHSS family	Thermal feature most sensitive to control	Typical production consequence of thermal excursion
DP	intercritical austenite fraction; ferrite recrystallization; cooling to martensite	strength/yield ratio and elongation shift; martensite fraction/morphology changes
TRIP / TRIP-assisted	austenite fraction, carbon partitioning and transformation path	retained-austenite amount/stability changes; strength-ductility balance shifts
Complex phase / martensitic grades	austenitization/intercritical state and high cooling rate	strength, hardness and toughness variation; incomplete target transformation
3G / medium-Mn	austenite reversion, Mn/C partitioning and retained-austenite stability	narrower property window; strong changes in work hardening and elongation
All galvanized AHSS	surface selective oxidation during annealing	Zn wetting, inhibition-layer formation, bare spots and coating adhesion can change

Table 1. Practical relationship between AHSS metallurgy and thermal control. [16-19].

3. Emissivity Has Two Different Effects in the Furnace

Surface emissivity is often discussed only as a pyrometer setting. In a radiation-dominated annealing furnace it is also a heat-transfer property. For an opaque surface at thermal equilibrium, absorptivity and emissivity are linked by Kirchhoff's law. A strip that absorbs more of the incident furnace radiation will generally heat differently from a more reflective strip under otherwise identical conditions [5,12-15].

The full furnace calculation requires view factors, surface properties, multiple reflections, convection, strip movement and zone geometry, but the production meaning is straightforward: a change in strip radiative properties can change the actual heating rate. Published furnace models identify strip emissivity/radiative characteristics, strip thickness, speed and radiant-tube conditions as important thermal-model inputs [9-12].

At the same time, a pyrometer derives temperature from the radiation emitted by the strip. At one wavelength, the detected spectral signal is proportional to the spectral emissivity multiplied by the blackbody radiation at the true temperature. If the instrument or algorithm assumes the wrong emissivity, the indicated temperature is wrong even when the pyrometer electronics are perfectly calibrated [4,12-15].

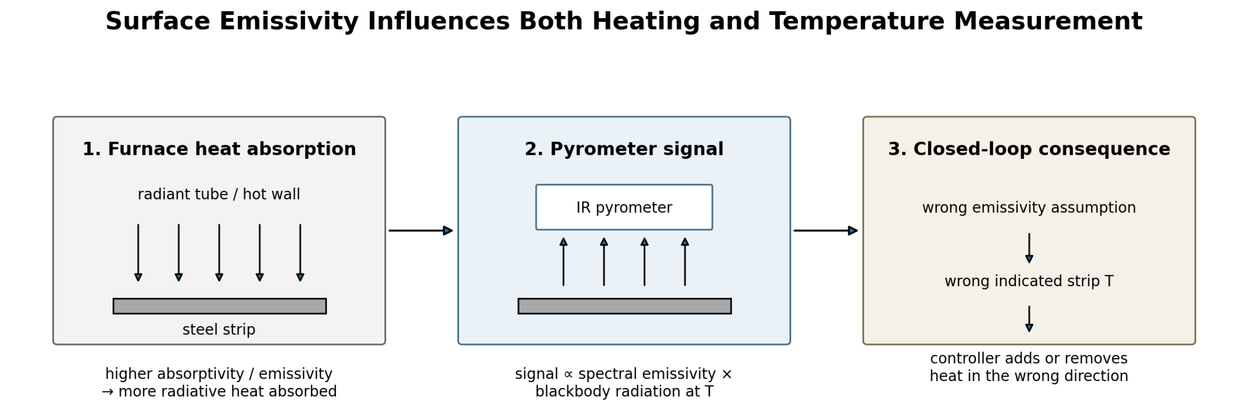

Figure 2. Surface emissivity has two production roles: it affects radiant energy absorbed by the strip and it affects the radiation signal used to infer strip temperature [4,9,12-15].

Illustrative size of a pyrometry error

Using a simplified single-wavelength Wien-law calculation at 1.6 μm, a strip actually at 850 degrees C with true emissivity 0.30 would be indicated at about 811 degrees C if the pyrometer were set to emissivity 0.40 - an error of roughly -39 degrees C. Reversing the mismatch (true 0.40, setting 0.30) gives an indicated temperature of about 892 degrees C, roughly +42 degrees C. This example ignores background reflection and is not a calibration procedure; it simply shows why modest emissivity changes can create production-significant temperature errors at AHSS annealing temperatures [12-15].

The closed-loop direction is important. With single-wavelength feedback, if actual emissivity falls below the value assumed by the instrument, the pyrometer tends to read low. A temperature controller may respond by adding heat and can therefore overheat the strip. If actual emissivity rises above the assumed value, the indicated temperature can be high and the controller can underheat the strip. In multi-wavelength systems the direction and magnitude depend on the spectral emissivity model and cannot be reduced to one simple rule [13-15].

4. What Emissivity Means for Production Pyrometry

Emissivity is not one universal number for steel. The quantity relevant to an infrared pyrometer is spectral, directional emissivity at the wavelengths and viewing geometry of the instrument. It varies with wavelength, temperature, surface chemistry, roughness, oxide morphology and viewing direction. Consequently, an emissivity value obtained with a long-wave thermal camera at 100-300 degrees C cannot automatically be used for a near-infrared furnace pyrometer operating near intercritical annealing temperatures [12-15,20].

Older industrial thermometry work already demonstrated that strip emissivity depends on strip specification, temperature and detector wavelength and that reflected furnace radiation can become a major error source for low-emissivity strip. Modern AHSS adds further variability because selective oxidation changes the near-infrared radiative properties as the strip is heated [4,12-15].

Single-wavelength pyrometry requires an assumed emissivity. Two-color or ratio pyrometry uses the ratio of signals at two wavelengths and is less sensitive to some common-mode losses, but it still requires an assumption about the ratio of spectral emissivities at the two wavelengths. For a true greybody that ratio would be one. AHSS surfaces are often not grey over industrial near-IR wavelengths, especially while selective oxides are evolving [13-15].

Multi-wavelength methods use three or more spectral channels and an emissivity model. They can reduce uncertainty when the model captures the material behavior, but they do not remove the need to understand emissivity. Research on DP980 showed that emissivity depends on interacting effects of alloy composition, wavelength, pre-annealed surface state and dew point; model quality therefore matters [14,15].

Recent research is moving toward conditional and data-driven emissivity compensation rather than one fixed recipe value. A 2026 open-access study on DP780, DP980 and IF steel used emissivity priors conditioned on annealing dew point and brightness temperature to improve Bayesian pyrometry, while a 2024 study demonstrated that surface imagery and topography can be used to infer radiative-property variations across AHSS coils [24,25]. These approaches are promising for production, but they still require plant-specific validation and reliable surface-state inputs.

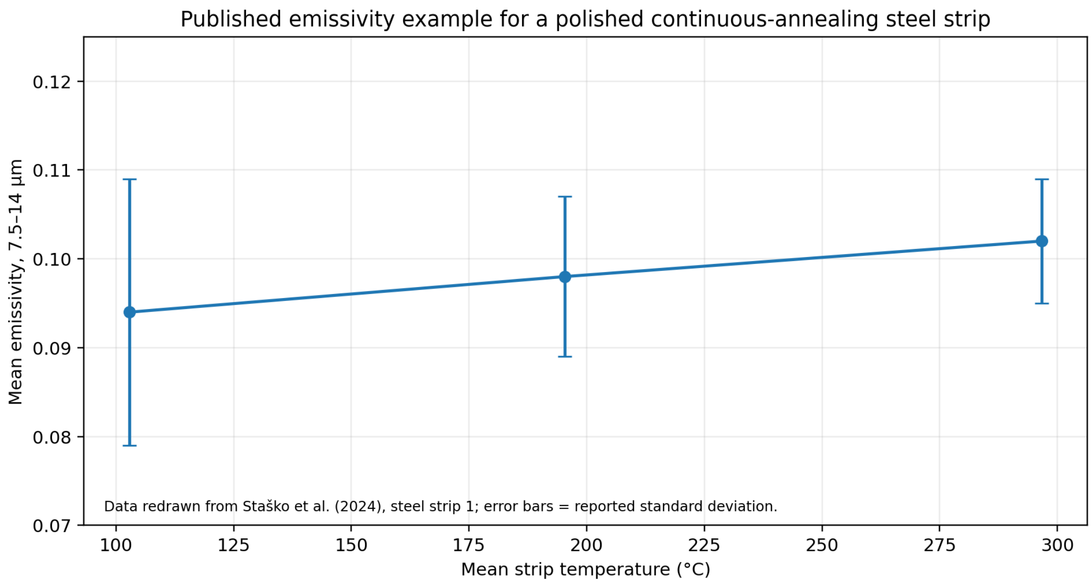

Figure 5. Literature example: mean long-wave emissivity measured on one polished steel strip increased from about 0.094 near 100 °C to about 0.102 near 300 °C; error bars show the reported standard deviation. Data redrawn from Staško et al. [20], an open-access CC BY study. The wavelength and temperature range differ from near-IR AHSS furnace pyrometry, so the values should not be transferred directly to CGL annealing control.

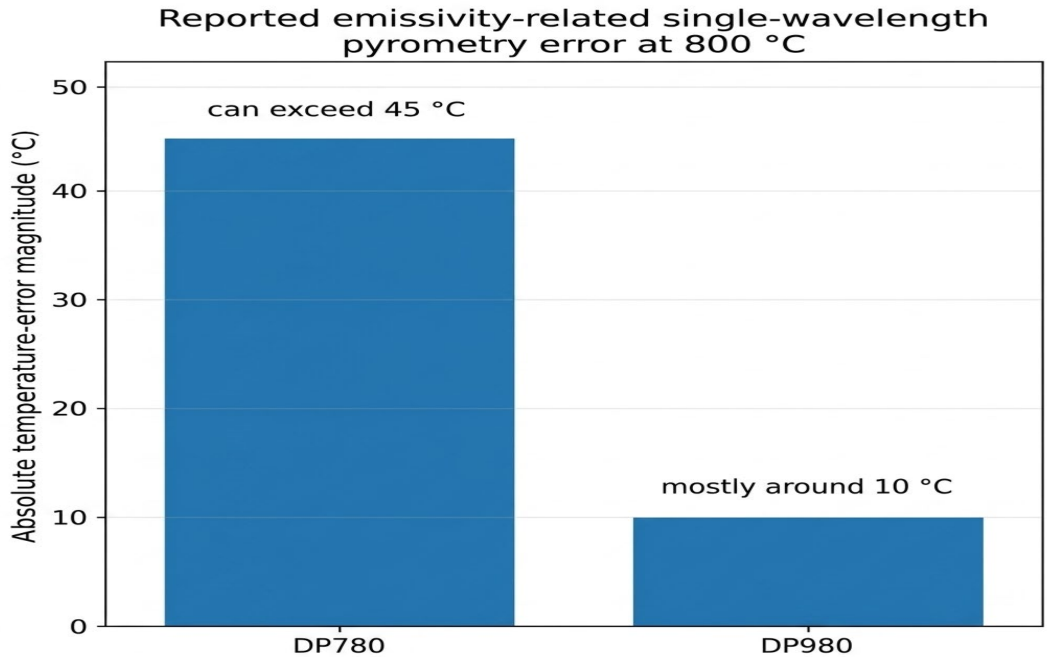

Figure 6. Literature example of the production significance of emissivity evolution. Somveille [22] estimated that, at a nominal 800 °C and over 1–2.5 µm, using the as-received emissivity rather than the annealed surface emissivity could produce errors exceeding 45 °C for the studied DP780 and mostly around 10 °C for the studied DP980. Redrawn from the reported results; these values are material- and condition-specific.

Method	Strength	Main production limitation / validation need
Single-wavelength direct view	simple; fast; mature	requires valid emissivity setting and control of reflected furnace radiation
Two-color / ratio	less sensitive to equal attenuation and partial field-of-view effects	assumes known emissivity ratio; AHSS spectral emissivity ratio can evolve
Multi-wavelength	can fit a non-greybody emissivity model	algorithm/model must represent the grade and evolving surface state
Roll-strip wedge / cavity	multiple reflection increases apparent emissivity and suppresses hot-wall reflection	requires correct alignment, field of view and small strip-roll temperature difference
Temperature-measuring roll / contact reference	valuable for calibration and emissivity characterization	not available at every furnace position; response/contact assumptions must be validated

Table 2. Temperature-measurement approaches used in continuous annealing and galvanizing practice [4-8,13-15].

5. Why AHSS Surface Emissivity Changes During the Coil

The entry surface of cold-rolled strip already contains a radiation signature created by work-roll texture, roughness, local waviness, residual oil/cleaner condition and chemistry. Rough metal surfaces can absorb more radiation through multiple reflections between microscopic surface features, while smooth bright surfaces are more specular and can have very low emissivity [13,20].

During annealing, the surface state changes. Mn, Si, Al and Cr have stronger affinities for oxygen than Fe and can selectively oxidize even in N2-H2 atmospheres that are reducing to iron. Depending on alloy composition, temperature and atmosphere, oxides may form as films, nodules or mixed internal/external structures. These nanoscale to sub-micron features change optical constants, surface coverage, roughness and interference behavior and therefore change spectral emissivity [2,15,16,21,22].

Research on AHSS radiative properties has shown two principal physical contributions. Thin or semi-continuous oxide layers can create wavelength-dependent interference effects. Surface roughness and irregular oxide morphology create scattering and multiple-reflection effects. Industrial surfaces frequently contain both mechanisms at the same time, which is one reason a single fixed emissivity or fixed two-color e-slope can be unreliable over an entire campaign [13-15].

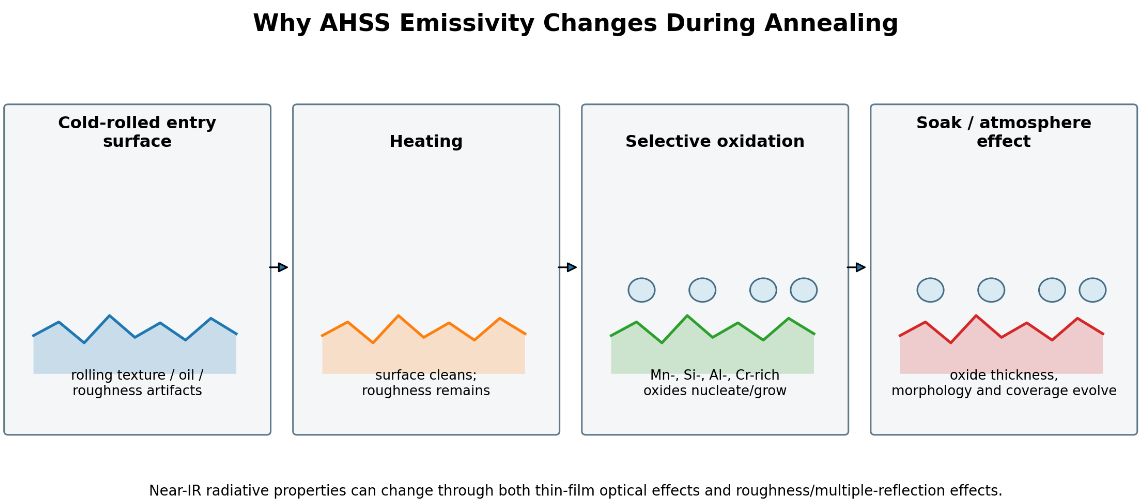

Figure 3. Simplified evolution of AHSS surface state during annealing. Rolling roughness and selective oxidation jointly change spectral emissivity [13-16,21].

Important for coil-to-coil consistency

Two coils sold under the same grade designation can have different entry-surface roughness, pickling/cleaning condition, chemistry within specification, and oxide response. If a pyrometer recipe is indexed only by grade name, the residual surface variability can still appear as apparent temperature drift.

6. Annealing Atmosphere, Dew Point and Emissivity Are Coupled

For AHSS, atmosphere control is usually introduced to solve surface-oxidation and galvanizability problems. It must also be recognized as a pyrometry variable. Increasing or decreasing dew point changes the effective oxygen potential at the strip surface and can change whether Mn-, Si-, Al- and Cr-containing oxides form externally, internally or as mixed morphologies. Because these oxides influence near-IR emissivity, a dew-point change can shift the relationship between true strip temperature and pyrometer signal [2,15,16,21,22].

A commonly used galvanizability strategy is to use a higher dew point in selected furnace zones to promote internal oxidation rather than continuous external oxidation of alloying elements. This can improve the availability of metallic Fe for reactive wetting by the Zn bath. However, the optimum dew point is chemistry- and temperature-dependent; recent work also shows that the response of high-Al AHSS can be non-monotonic and more complex than a simple rule that higher dew point always reduces problematic external oxides [16,21].

For production teams, the important point is that furnace atmosphere and pyrometry cannot be maintained as separate control disciplines. When a dew-point recipe is changed to improve coating quality, emissivity/e-slope assumptions and strip-temperature validation should be reviewed at the same time. Otherwise, a coating improvement trial can unintentionally shift the actual annealing thermal cycle.

High dew points can also increase the risk of near-surface decarburization in some grades because carbon can react with oxygen-bearing species to form CO/CO_2. Decarburization, selective oxidation, phase transformation and emissivity are therefore linked through the same atmosphere-temperature-time history and should be assessed together when process windows are pushed [2,19].

7. Reflected Furnace Radiation: The Other Major Pyrometry Error

Bright steel has low emissivity and therefore high reflectivity. A direct-view pyrometer does not see only radiation emitted by the strip; it can also receive hot-wall or radiant-tube radiation reflected from the strip into the detector. When strip emissivity is low, this reflected component can be comparable to or larger than the emitted component and can make the strip appear hotter than it really is [4,5].

Practical countermeasures include viewing geometry that prevents the pyrometer from seeing a reflected image of hot furnace surfaces, cooled or shielded sight tubes, and roll-strip wedge arrangements. The wedge method exploits multiple reflections between the strip and roll to create a high apparent emissivity cavity and has been demonstrated for bright strip. Its performance depends on alignment, field of view, wavelength and the temperature difference between strip and roll [5,6].

Optical cleanliness is equally important. Furnace windows, sight tubes and lenses can accumulate deposits or become partially obscured. Transmission loss may not affect all wavelengths equally. A two-color instrument can reject equal attenuation at both wavelengths but not necessarily wavelength-dependent contamination. Optical condition should therefore be a tracked maintenance parameter, not only a response after quality problems occur.

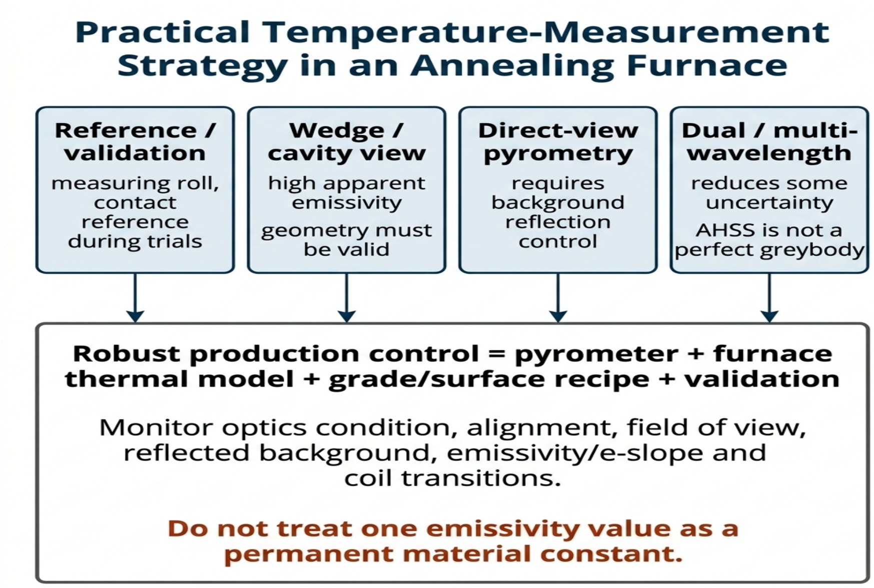

Figure 4. Robust CGL thermometry combines appropriate viewing geometry, emissivity treatment and an independent validation route. No single measurement method removes every error source [4-8,13-15].

8. Practical Furnace-Control Architecture

A robust annealing control strategy normally combines feed-forward calculation and feedback correction. Furnace thermal inertia and strip residence time mean that feedback alone is too slow during many transitions. A grade or gauge change can enter the furnace before the outlet pyrometer reveals the full consequence [9-11].

The feed-forward layer should use variables that determine strip thermal response: entry strip temperature, thickness, line speed, grade/thermal-property family, width where relevant, furnace-zone availability and planned PAT/cooling trajectory. The furnace model then predicts the required zone firing or radiant-tube temperatures. Feedback pyrometers correct model bias and disturbances. Model-based control has been demonstrated as suitable for continuous annealing because it can represent the distributed thermal process and time delay while remaining fast enough for online use [9-11].

For AHSS, an additional surface-state layer is useful. Production recipes can include validated emissivity or e-slope information by grade family, surface condition and annealing-atmosphere regime. Where multi-wavelength instruments are used, the stored model coefficients should be version-controlled in the same way as metallurgical furnace recipes. A pyrometer algorithm change is a process change.

The control hierarchy should also distinguish steady-state and transient operation. During a stable campaign, outlet feedback can maintain tight control. During welded transitions, speed changes, burner-bank changes or atmosphere transitions, a predictive model is especially valuable because the process contains long lags and each strip segment experiences a different moving thermal environment [9-11].

Control input / signal	Why production needs it	Common failure mode if ignored
Strip thickness	sets thermal mass per unit area	thin/thick transition creates over/under-temperature
Line speed	sets residence time in every furnace section	speed correction changes PAT and soak simultaneously
Entry strip temperature	changes required furnace duty	seasonal/cleaning-section variation appears as furnace drift
Grade / chemistry family	changes target microstructure and selective oxidation	wrong recipe or emissivity model after grade change
Surface roughness / finish family	changes absorption and spectral emissivity	same grade reads differently between coils/suppliers
Dew point / H2 by zone	controls oxide state and hence galvanizability/emissivity	coating trial changes pyrometer bias
Pyrometer signal quality	confirms optics, FOV and algorithm validity	controller chases a bad measurement
Thermal model residual	difference between predicted and measured strip T	slow sensor drift or emissivity change remains hidden

Table 3. Practical inputs for a production-grade annealing temperature-control system.

9. What Happens During Grade, Gauge and Speed Transitions

Transitions are where weak control strategies are most often exposed. Furnace walls, radiant tubes and rolls store substantial thermal energy, so the furnace state does not instantly follow a new recipe. At the same time, the welded strip may change thickness, width, chemistry and surface emissivity within seconds at the line entry. Published models show significant time lags after changes in line speed, strip thickness and radiant-tube temperature [9-11].

A common production mistake is to treat the new pyrometer reading as an immediate representation of the new coil. Depending on furnace length and sensor location, the instrument may still be viewing the previous grade or a mixed transient region. Coil tracking and segment tracking must therefore be synchronized with the furnace model and pyrometer locations.

When the next product has lower true emissivity at the controlling wavelength, a fixed-emissivity pyrometer may indicate a temperature drop even before the actual strip temperature has fallen by the same amount. If the controller aggressively increases firing, the transition material can be overheated. Conversely, a more emissive surface can appear hotter and lead to underheating. This is a reason to limit feedback authority during known emissivity transitions until the thermal model and signal plausibility checks agree.

Operationally, transitions should have explicit rules for permissible speed ramps, zone setpoint ramps, atmosphere stabilization time, pyrometer-recipe switching position and disposition length around the weld. These rules are line-specific but should be based on strip travel time and furnace dynamic response rather than on a fixed number of meters by habit.

10. Production Troubleshooting: Symptoms, Checks and Likely Mechanisms

Observed production symptom	Possible temperature/emissivity mechanism	First checks on the line
Strength high / elongation low	actual PAT higher than indicated; excessive austenite/martensite fraction; cooling interaction	compare thermal-model prediction vs pyrometers; check emissivity recipe, optics, speed/gauge transition
Strength low / incomplete DP response	actual PAT/soak lower than intended; incomplete recrystallization/austenite formation	verify pyrometer bias against reference; confirm firing limits and strip residence time
Mechanical properties drift head-to-tail	surface state/emissivity evolves or furnace atmosphere drifts; model mismatch	trend dew point, H2, pyrometer signal quality, model residual and entry surface data
Bare spots / poor wetting but mechanical properties acceptable	selective external oxides despite adequate bulk thermal cycle	check dew point by zone, actual PAT, surface chemistry; do not solve only by changing Zn pot conditions
Coating improves after dew-point change but properties shift	dew-point change altered emissivity and therefore actual thermal cycle	revalidate pyrometer/e-slope after atmosphere modification
Pyrometer oscillation / unstable firing	reflections, FOV/alignment, contaminated optics, moving strip shape, emissivity transition	inspect sight path; compare second sensor/model; reduce controller authority until signal validated
Difference between two pyrometers grows with grade	wavelength-dependent emissivity or different reflected background	check wavelength/algorithm assumptions and viewing geometry; compare on stable reference grade
Temperature okay at steady state, failures near welds	furnace lag and recipe timing / tracking error	verify weld tracking to each furnace zone and sensor; review transition ramp strategy

Table 4. Production troubleshooting guide. The listed mechanisms are diagnostic hypotheses, not automatic root-cause conclusions.

11. A Practical Validation Procedure for Production Lines

A good temperature-control system is not validated only by the calibration certificate of the pyrometer. It is validated by demonstrating that the inferred strip temperatures generate the expected thermal response and product state over the relevant grade, gauge, speed and atmosphere range. Historical work used intermittent contact thermometers or temperature-measuring rolls to establish emissivity and verify radiation thermometry; the same principle remains valid even if modern reference methods differ [4,7].

1. Define the critical measurement points: heating exit, PAT/soak, cooling exit and bath approach where applicable. Record wavelength, field of view, angle, optics and background environment for every pyrometer.

2. Establish a traceable reference route. Depending on line design this may use a temperature-measuring roll, instrumented trial strip, validated contact method during commissioning, or a well-characterized cavity/wedge location.

3. Validate by product family, not only on one low-alloy reference. Include at least representative low-emissivity bright strip, DP/AHSS chemistries and the dew-point regimes used in production.

4. Trend model residuals. A persistent difference between predicted and measured strip temperature can indicate emissivity drift, optics fouling, burner/radiant-tube degradation or wrong material data.

5. Run atmosphere-change validation. Any substantial change in dew point, H2 content, oxidation/reduction strategy or pre-cleaning should trigger a review of radiative-property assumptions.

6. Check transient behavior. Validate the system during gauge, speed and grade transitions, not only during steady-state campaigns.

7. Correlate thermal data with product outcomes: tensile properties, retained-austenite or phase data where available, galvanizability/coating defects and surface-oxide characterization during development trials.

8. Freeze and version-control the validated recipe set. Treat changes to emissivity, e-slope, multi-wavelength coefficients, sight geometry or firmware algorithms as controlled process changes.

12. Common Non-Advantages and Limitations of Pyrometry-Based Control

Non-contact thermometry is indispensable on moving strip, but it has inherent limitations. Production teams should avoid assuming that a more sophisticated pyrometer automatically eliminates process uncertainty.

A calibrated detector can still report the wrong strip temperature if emissivity or reflected background is wrong.

Two-color pyrometry is not automatically emissivity-free. It requires the emissivity ratio at the two wavelengths to be known or sufficiently stable [13,14].

Multi-wavelength algorithms can be more robust, but only if their emissivity model represents the actual AHSS surface state [14,15].

A wedge/cavity method can strongly reduce emissivity sensitivity, but alignment, roll-strip temperature difference and field-of-view constraints remain [5,6].

Laboratory emissivity data measured at another wavelength, temperature range or surface preparation may not be transferable to the production pyrometer [20].

Furnace thermal models are only as good as their boundary conditions. Incorrect emissivity, strip tracking, radiant-tube temperature or entry conditions can create a precise but wrong prediction.

Mechanical-property confirmation remains essential during new-grade development. Temperature measurement is an enabling process variable, not a substitute for metallurgical qualification.

13. Surface Emissivity and Heating Uniformity Across Strip Width

Most production discussions focus on average strip temperature, but radiative heating also has a widthwise component. Strip edges have different view factors, edge geometry and often different roughness from the rolled faces. Models of radiant annealing furnaces show that edge heating can differ from center heating and that the magnitude depends on strip emissivity and furnace geometry [12].

This becomes relevant for wide AHSS strip, shape-sensitive products and electrically heated furnaces with high radiative heat flux. A centerline pyrometer cannot identify every widthwise temperature gradient. Where edge mechanical-property or coating variation is recurrent, the investigation should consider widthwise thermal modeling, scanning pyrometry/thermal imaging where technically valid, heater/radiant-tube distribution, strip position and edge emissivity in addition to conventional flatness causes.

Recent work on electrically heated continuous annealing furnaces continues to show the importance of temperature-dependent emissivity, strip speed, heater placement and widthwise radiative geometry. Electrification changes the heat source but does not remove emissivity from the heat-transfer problem [23].

14. Practical Production Checklist

Before campaign	During production	After an unexplained deviation
Confirm grade/gauge/speed recipe and correct pyrometer model or emissivity setting.	Trend strip T, zone firing/RT temperatures, speed, dew point and model residual on one timeline.	Freeze raw trend data before resetting controllers or changing recipes.
Check sight glass/tube cleanliness and sensor alignment.	Watch transition zones around welds and atmosphere changes.	Compare direct-view, wedge/reference and thermal-model temperatures where available.
Confirm dew point/H2 analyzers and furnace-zone atmosphere stable.	Use signal-quality/emissivity diagnostics if instrument provides them.	Check whether surface finish or chemistry changed within specification.
Verify furnace is not at firing/cooling capacity limit.	Do not compensate a suspected bad pyrometer by permanently biasing furnace setpoints without validation.	Inspect optics, reflected-background geometry and strip tracking before changing metallurgical PAT.
Confirm coil tracking and recipe switch position.	Record deviations with coil length / strip position, not only clock time.	Correlate with tensile/coating data and retain samples from affected strip length.

Table 5. Operator/process-engineer checklist for AHSS annealing temperature control.

15. Recommended Production Philosophy

The most robust way to manage AHSS annealing is to treat temperature measurement, furnace heat transfer, atmosphere chemistry and product metallurgy as one control problem. Separate ownership of furnace operation, pyrometry, atmosphere and metallurgy is organizationally common, but the physical process is coupled.

A practical hierarchy is:

1. Start with a metallurgically justified target thermal trajectory and atmosphere window for the grade.

2. Use a dynamic furnace model for feed-forward control through gauge, speed and grade changes.

3. Measure strip temperature at the most representative locations with geometry and wavelengths appropriate to low-emissivity steel.

4. Compensate emissivity using validated grade/surface models, cavity methods or multi-wavelength approaches rather than one permanent generic steel value.

5. Use independent reference measurements and product outcomes to detect slow measurement bias.

6. Treat atmosphere changes as both surface-chemistry changes and radiative-property changes.

7. Trend model residuals and pyrometer health indicators so that measurement degradation is detected before it becomes a mechanical-property rejection.

16. Conclusions

1. AHSS production in a CGL is controlled by the actual strip temperature-time trajectory. Furnace-zone temperatures and firing rates are necessary control variables but are not direct measures of product thermal history.

2. Peak annealing temperature and residence time determine phase evolution, recrystallization and austenite formation. Subsequent cooling determines transformation products. The allowable window can be narrow for DP, TRIP and third-generation AHSS.

3. Surface emissivity has two independent production effects: it changes how the strip absorbs radiant furnace heat and it changes how infrared pyrometers infer strip temperature.

4. AHSS emissivity is spectral and evolves with wavelength, temperature, cold-rolled surface roughness, alloy composition and selective oxidation. It should not be treated as one permanent material constant.

5. Mn, Si, Al and Cr selective oxidation links annealing atmosphere to pyrometry. Dew-point changes made to improve galvanizability can also change near-IR emissivity and therefore the pyrometer bias.

6. Low-emissivity strip strongly reflects furnace radiation. Direct-view pyrometry therefore requires control of reflected background through suitable geometry, shielding or cooled sight arrangements.

7. Two-color pyrometry reduces some measurement problems but is not automatically emissivity independent. The spectral emissivity ratio of AHSS can change during annealing. Multi-wavelength approaches can improve robustness when the emissivity model is validated for the relevant surface states.

8. Roll-strip wedge/cavity methods and temperature-measuring rolls remain valuable because they provide high-apparent-emissivity or independent reference conditions, but they also have geometry and temperature-difference limitations.

9. Grade, gauge and speed transitions require feed-forward control because furnace thermal inertia and strip travel time create significant process delay. Outlet feedback alone cannot reconstruct the full upstream thermal trajectory.

10. Production troubleshooting should compare pyrometer readings with thermal-model predictions, atmosphere data, optics condition, coil tracking and product results before changing metallurgical temperature targets.

11. The best long-term control strategy is an integrated one: metallurgy + furnace thermal model + validated pyrometry + atmosphere control + product feedback. This approach reduces both mechanical-property variation and galvanizing surface defects.

GalvInfo key message

For AHSS, a pyrometer reading is not automatically the strip temperature. It is a radiation-based estimate whose accuracy depends on the evolving surface. Production control should therefore manage emissivity as a process variable and validate the complete temperature-time-atmosphere trajectory, especially after changes in grade, surface finish, dew point, gauge or line speed.

References

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Scope and use

This GalvInfoNote summarizes general technical principles and published research. Target annealing temperatures, dew points, cooling rates, pyrometer settings and control limits are grade- and line-specific and should be established through plant trials, metallurgical qualification and equipment-specific calibration.

Contact the GalvInfo Center

For technical assistance, contact the GalvInfo Center at info@galvinfo.com.

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