Introduction

The locally prevailing air temperature, the moisture content in the air (% relative humidity), and the temperature at which moisture will condense on surfaces (dew point) are commonly called the ambient conditions. If these conditions are not within the ranges required by a coating specification during surface preparation or coating application, problems in obtaining a protective film with a long-term performance are likely to occur.

Because of concerns for these problems, specifications require the monitoring of ambient conditions using specialized instruments and test methods before the start of work and periodically during the work. Measurement of these conditions is especially important when weather conditions change during the course of a work shift.

Common Coating Defects Related to Adverse Ambient Conditions

Some of the most commonly occurring coating defects related to unfavorable ambient conditions are discussed in the next few paragraphs. The tendency for such defects to occur is often related to changes in local weather after the work has begun.

Low Temperatures

Adverse effects of low temperatures are most commonly related to the complete and proper curing of coatings within a reasonable amount of time:

Slow curing of coatings. Slow curing will permit the accumulation of wind-borne dirt, mildew spores, and other undesirable surface contaminants. It will also increase the time during which the painted surfaces must be isolated from traffic or other construction work to avoid damage or contamination.

Incomplete curing. Many latex coatings applied below 40 °F will not coalesce to form durable films. Also, thermosetting coatings that cure by chemical reactions of two parts or by reaction with oxygen in the air will have a much longer curing time and may never cure completely.

Improper curing. At low temperatures, many thermosetting (e.g., two-part) coatings may cure by mechanisms other than that intended by the formulator.

Incomplete leveling. Low temperatures may reduce the viscosity (fluidity) of a coating applied to a surface, so that it cannot level properly (flow together to form a uniformly thick film). When brushing, incomplete leveling may result in brush marks in the cured film; when spraying, incomplete leveling may result in orange peel (irregular thicknesses in the cured film resembling an orange skin).

High Temperatures

Adverse effects of high temperatures on coatings are usually related to their accelerated drying or curing rates:

Re-rusting. High temperatures accelerate the rusting of cleaned steel.

Rapid drying of lacquers. Coatings called lacquers form a protective film on substrates merely by evaporation of the solvent in which their resins are dissolved. Accelerated evaporation of the solvent during spray application at high temperatures may result in an inability of the wet film to flow together (level) to form a continuous film of even thickness. This results in dry spray (formation of a rough surface with pinholes or voids).

Rapid drying of latex coatings. Latex coatings (dispersions of resins in water) form a protective film by coalescence of their resins as the water evaporates. If temperatures exceed those recommended by the manufacturer, rapid drying will cause a low quality protective film to be produced.

Rapid curing of coatings. Most coatings cure to form a protective film by a chemical reaction, either between separately-packaged paint components, or with water or oxygen in the air. These chemical reactions are accelerated at high temperatures to cause more rapid curing of coatings. Rapid curing often results in significant shrinkage, stresses, and other harmful effects on the coating.

Effects of exotherm. The reaction of separately-packaged chemically-curing coatings generates a heat called exotherm when the two parts are mixed together. This exotherm, along with a prevailing high temperature, may further accelerate the curing rate to cause harmful effects on coatings. Also, the exotherm may reduce the viscosity significantly to interfere with normal application or curing of the coating. The greater the volumes of Parts A and B that are mixed together for application, the greater will be the exotherm and its harmful effects.

* Although this monograph has undergone peer review, it is not an official SSPC standard developed through SSPC’s standards development process.
Reduced induction time. The induction time for two-part, chemically-curing coatings is the time required to produce an exotherm that will cause the chemical curing of the coating to continue to completion. Induction times will be shortened or may not even be necessary at high temperatures.

Reduced pot life. The pot life of two-part, chemically-cur- ing coatings is the period of time after mixing and induction (if any) during which the coating can successfully be applied. If the pot life is exceeded, the mixed product is too viscous (thick) for proper application. In addition to the high ambient temperature, the exotherm will further reduce the pot life.

Reduced recoat window for topcoating. Two-part, chemically-curing coatings can only be topcoated successfully in the limited time range specified by their manufacturer. If the next coat is applied too soon or too late, harmful results will occur to the protective film. The recoat window of time will be significantly reduced at high temperatures.

Wrinkling. At high temperatures, alkyd and other drying oil-containing coatings that cure by reaction with oxygen in the air may react rapidly at the coating surface to form a skin that will not permit further oxygen penetration to cure the underly- ing coating. Shrinking of the skin results in wrinkling of the coating surface to form rows and furrows with uncured coating beneath. Wrinkling is more likely to occur if these coatings are applied in a thick heavy coat.

Pinholes in topcoats of inorganic zinc-rich coatings. When topcoating inorganic zinc-rich coating films, rising tem- peratures may cause air or solvent vapors entrapped in the pores of the films to be emitted and rise to the surface of the wet topcoats. This will cause pinholes to form in the topcoats.

Outgassing from concrete. Rising temperatures during the coating of bare concrete may cause air entrapped in its pores to be emitted and rise to the surface of the wet film to leave pinholes in it. Sealing of the concrete will reduce the tendency to form pinholes by outgassing.

Low Humidities

Harmful effects of low humidities are usually associated with changes in coating curing rates:

Incomplete curing of inorganic zinc-rich coatings. Solvent-borne inorganic zinc-rich coatings require moisture from the air for curing. On dry days, it may be necessary to spray water onto these coatings for complete curing.

Curing of polyurethane and polyurea coatings. Single-part polyurethane and polyurea coatings cure by reaction with moisture in the air. Unless the humidity is above 20%, the coatings will not cure satisfactorily.

Curing of water-borne coatings. On hot, dry days, wa- ter-borne coatings may cure so fast that they do not produce durable films.

High Humidities

Flash rusting. High humidities will greatly accelerate re- rusting (flash rusting) of cleaned steel. This is why dehumidifiers are often used to reduce the humidity in closed spaces.

Reduced bonding strength. Moisture condensed on cleaned surfaces, with or without rusting, may reduce the bonding strength of the coatings to the surfaces.

Blushing of lacquers. High humidities may cause solvent blushing during spray application. The rapidly evaporating sol- vent reduces the temperature at the surface of the wet coating film to the dew point, and moisture condensation occurs.

Blistering. Condensed water on surfaces being coated may cause blistering of the coatings.

Improper curing of coatings. If the ambient humidity is over 80%, moisture in the air will react so rapidly with the single-part (moisture-curing) polyurethane and polyurea coat- ings, that these reactions compete with the intended curing reactions, and durable protective films cannot be achieved. Because of their reactions with moisture, exposure to air of moisture-curing polyurethane and polyurea coatings should occur only during actual application.

High Dew Points

It is a common rule that the surface temperature must be at least 5 °F above the dew point and not falling to prevent moisture condensation. Harmful effects of moisture condensation on protective films were discussed in the previous paragraph.

High Winds

High winds (above 15 miles per hour) at job sites may also have harmful effects on coating operations:

Contamination of cleaned surfaces. Winds may blow dirt, dust, and other debris onto cleaned surfaces. Unless removed before painting, this contamination will reduce the bond strength of coatings applied to the contaminated surfaces.

Contamination of uncured coatings. Wind may blow dirt, dust, and other debris onto the uncured coating. This will produce an unsightly appearance to finish coats. If a topcoat is to be applied over the contaminated coating, the contamina- tion will reduce the bond strength of the topcoat to the undercoat.

Overspray. High winds make control of overspray more difficult. Wet paint mist may be carried outside the paint area onto automobiles or other unintended surfaces.

Exterior application of paint should cease when wind velocity reaches 25 miles per hour or more, either in gusts or at a steady state. Where surfaces can be shielded from wind by artificial deflection means, work may continue.

Ambient Conditions to Monitor/Track

Relative Humidity and Dew Point

Instruments used to measure percent relative humidity and dew point are called psychrometers. The three basic types of psychrometer are:

Sling psychrometer. A sling psychrometer has two ther- mometers, the bulb of one of which is fitted with a cotton sock soaked in water. As the thermometers are whirled through the
air, water evaporates from the wet sock to lower the “wet bulb thermometer” below that of the “dry bulb thermometer”. Tables of the U.S. Weather Bureau are used to relate the amount of “temperature depression” to relative humidity and dew point.

Battery-powered psychrometer. A battery-powered psychrometer operates on the same principal as the sling psychrometer, but a fan is used to blow air across the thermometer.

Electronic psychrometer. Electronic psychrometers with special sensors are much more expensive and easy to use, but many are not suitable for exterior service. Others may perform continuous or intermittent monitoring.

Wind Velocity

Wind meters can be used to determine when wind speeds exceed specification requirements during coating application. The meter is positioned vertically in the wind stream, and its velocity is read directly from the scale. Digital wind meters are also available.

Surface Temperature

Although not really an ambient condition, the surface temperature of substrates is an important local condition that requires periodic measurement to ensure good coating performance. The three basic types of instruments for measuring substrate surface temperature are listed below in order of increasing price:

Dial thermometers. Dial thermometers have bi-metallic springs that expand with increasing temperatures to move the indicator needles on the thermometer faces higher on the scales. Magnets secured to the backs of the thermometers hold them in place on vertical steel surfaces.

Digital contact thermometers. Battery-powered digital contact thermometers utilize thermocouples to measure surface temperatures. This type of thermometer is usually the most accurate. These thermometers are often combined with electronic psychrometers in a single instrument.

Non-contact infrared thermometers. Battery-powered, non-contact thermometers utilize infrared light emitted from the surface to determine temperature. This instrument is also good for measuring the temperature of mixed coatings. Some electronic psychrometers also have surface temperature measuring capabilities.

Control of Ambient Conditions

The easiest way to conform to ambient condition requirements during coating operations is to blast and paint only during those times of the day when the conditions meet the specification or coating manufacturer’s requirements. This may require working at night.

Also, at many locations during the winter, ambient conditions can only be achieved in enclosed shops with climate controls. In these places, exterior painting operations should be scheduled for times of the year when conditions are more appropriate.

The atmospheric conditions in tanks and other enclosed spaces can readily be controlled by heating/cooling and humidification/dehumidification. Humidification may be required to fully cure inorganic zinc-rich coatings. Control of temperature and dew point can prevent rusting of an abrasive blasted steel surface virtually indefinitely.

Control of wind, as well as temperature and dew point/relative humidity, on exterior surfaces can be made using containment that isolates the work area. Containment can also control contamination of surrounding environments with particulate debris from abrasive blasting. SSPC-Guide 6, “Guide for Containing Debris Generated During Paint Removal Operations” describes various methods of containment and describes four classes or levels of containment.

Utilization of Information on Ambient Conditions

Information on ambient conditions and past histories of local conditions must be effectively utilized to minimize potential coating problems associated with improper ambient conditions. Coating personnel must be able to anticipate likely changes in ambient conditions and their potentially adverse effects. Measurements of ambient conditions should be made more frequently as any of the measurements approaches a permissible limit.

In the morning, typically, both the temperature and the dew point rise, and the relative humidity falls. As the sun gets higher in the sky, more favorable conditions may be anticipated. In the late afternoon, temperatures are expected to fall and humidities to rise, so that potential adverse effects must be addressed.

There are many case histories where the inspector received acceptable temperature measurement (e.g., 95 °F when the maximum temperature is 100 °F) in the morning but failed to take additional measurements later in the day as the temperature rose. The higher temperatures in the afternoon exceeded the upper permissible level and resulted in poor quality coating films.

Changes in weather conditions can be anticipated from local weather reports. Also, many locations are susceptible to rapid weather changes (e.g., sudden fogs near coasts, sudden rains in tropical areas, and sudden winds in mountainous areas). In such areas, it may be advisable to use quick-curing coatings to minimize coating damage by rain or wind before curing. Using smaller quantities of mixed two-component coatings with short pot lives may limit wasting of mixed coatings that cannot be applied during adverse conditions or kept overnight.

Other case histories of coating failures involve painting that started after acceptable humidity conditions were measured and continued when humidity conditions changed to unacceptable levels. This commonly occurred when offshore fogs unexpectedly came ashore to significantly raise the humidity.
The applicators continued the painting because they didn’t want to waste the mixed coating that couldn’t be kept overnight.

Measurements of ambient conditions serve no purpose unless coating workers utilize this information to anticipate changes that may produce harmful effects and take necessary actions to avoid them. Fortunately, suitable temperature and humidity conditions occur frequently during the painting season.