Surface preparation and the application of coatings and linings should be performed under optimal environmental conditions to help prevent failures. A variety of instruments are available to measure the five conditions that should be observed and monitored:

- Air temperature
- Surface temperature
- Relative humidity (RH)
- Dew-point temperature
- The difference between the surface and dew-point temperatures.

It is commonly known that most coatings will not dry properly at low temperatures and high RH. Less understood is the impact surface moisture has on the life and performance of materials.

Moisture forms on a surface when relatively warm, moist air comes into contact with it—a process called condensation. Moisture causes unprotected steel to rust. Trapped between a coating and a substrate, moisture likely will cause the coating system to fail prematurely.

Light condensation on blasted surfaces can be difficult to observe. Rather than detect this moisture, instruments are used to help assess the risk of moisture forming in the first place. Tests should be performed to calculate the dew-point temperature before, during, and after the coating process. Dew-point temperature should be compared to the surface temperature to ensure the two are far enough apart that moisture formation is unlikely.

Careful monitoring of atmospheric conditions and a good understanding of their impact on the quality and long-term health of coating and lining applications are important to all contractors and inspectors.
Environmental Conditions
AIR AND SURFACE TEMPERATURES

The first parameters necessary to assess the risk of moisture formation on a substrate are the temperature of the surface to be prepared or coated and the temperature of the air near that surface. At night, steel work usually radiates heat and is cooled below air temperature. During the day, it absorbs heat and usually is warmer than the air temperature.

Because surface temperature often is different from air temperature, especially for work performed outside, both temperatures should be monitored to avoid application problems should air or steel temperatures become too hot or too cold for satisfactory film formation. Application at incorrect temperatures can cause defects such as blistering, pinholing, cratering, dry spray, and mud cracking. The coating manufacturer should specify the maximum and minimum surface temperatures for applying a coating.

ASTM D3276, “Standard Guide for Painting Inspectors (Metal Substrates),” states that the minimum surface temperature for coating application usually is 40°F (5°C). It may be as low as 0°F (–18°C) for “cold-curing” one- or two-component systems or up to 50°F (10°C) for conventional two-component systems. Paint specifications may further state that painting should not be undertaken when the temperature is dropping and within 5°F (3°C) of the lower limit.

The maximum surface temperature for coating application typically is 125°F (50°C) unless clearly specified otherwise. A surface that is too hot may cause the coating solvents to evaporate so fast that application is difficult, blistering takes place, or a porous film occurs.

RELATIVE HUMIDITY

Cure rates are directly affected by RH—the amount of moisture in the air expressed as a percentage of the total amount (saturation) possible at a given temperature. Moisture-laden air cannot hold as much solvent as dry air. Therefore, high RH can retard the rate of solvent evaporation. For this reason, the maximum RH at which coatings or linings can be applied and cured generally is set at 85%. Some coatings, however, require moisture to cure. Therefore it is important to check the specifications of the coating.

DEW-POINT TEMPERATURE

The dew-point temperature is the temperature at which moisture will begin to form on a steel surface. It is the temperature to which a volume of air must be cooled in order to reach saturation. It is a function of air temperature and RH.

DELTA (DIFFERENCE) BETWEEN DEW-POINT AND SURFACE TEMPERATURES

The final parameter is the amount of separation between the surface temperature and the dew-point temperature. Moisture likely will form if the temperatures are the same. Even if they are close, the risk of moisture forming may be unacceptably high. Documents such as ASTM D3276 and the international standard ISO 8502-4 state that the surface temperature must be a minimum of 5°F (3°C) above the dew-point temperature during the critical three phases of coating: preparation, application, and cure. This minimum separation also helps allow for surface temperature reduction as solvents evaporate or when cold coating materials are applied.

Instrumentation
MECHANICAL MEASUREMENT DEVICES

The air temperature, dew-point temperature, and the RH can be determined with a sling or battery-operated psychrometer. These instruments are equipped with two thermometers. The first thermometer, called a “dry bulb,” measures the ambient air temperature. The second thermometer is wrapped in a muslin sock or wick that is wetted prior to use—hence the name “wet bulb.” This “wet-bulb temperature” represents the heat loss from the evaporation of water in the sock. Low RH will cause a faster rate of evaporation and a lower wet-bulb temperature than high humidity.

The sling psychrometer (Figure 1) is twirled through the air to obtain the two temperature values. The electric psychrometer remains stationary as a motor-driven fan draws air across the thermometers.

Read the directions carefully. The instrument should be inspected and properly prepared before every test. Inspect the damp covering regularly.
and keep it in good condition. The evaporation of the water from the muslin always leaves a small quantity of solid material. It is therefore desirable to use water as pure as possible and also to renew the muslin periodically.

The physical location of the test and the amount of time spent whirling or blowing air over the wet bulb are factors that directly affect the accuracy of the test result. The thermometers should be whirled rapidly for 15 or 20 s, stopped, and quickly read—the wet bulb first because it will begin to change when the air movement stops. The test should be repeated until two or more wet-bulb readings equal the lowest reading obtained.

For best accuracy, the psychrometer should be whirled in the shade. The observer should face the wind and step back and forth a few steps to prevent body heat from adversely affecting observations. Be aware that when the temperature is near or below the freezing point, the psychrometer is not a very reliable instrument with which to measure humidity.3

A psychrometer does not directly measure RH and dew-point temperature. These values are calculated using a formula into which the dry and wet bulb temperatures are inserted. Graphs and psychrometric slide-rule calculators are available for this. Charts such as the U.S. Weather Bureau Psychrometric Tables (Figure 2) make this determination a little easier. Select the table corresponding to the local atmospheric pressure for that day; this value can be obtained from various sources, such as airport weather offices. Generally, 30 in. (76 cm) of mercury is used and corresponds to sea level. At higher elevations, use 23 to 29 in. (58 to 74 cm).

Read the thermometers carefully because there are many opportunities for interpolation errors. Slight differences in the values obtained from temperature scales and humidity lookup tables can cause considerably different results.

Here is an example: Assume that both thermometers read in 1-degree increments but that one could interpolate to a 1/2-degree. Given a typical ±1 degree accuracy, if the indicated dry-bulb temperature was 75°F (23.9°C) and wet-bulb temperature was 73°F (22.8°C), possible recorded values could resemble those shown in Table 1.

Although both thermometer values are within tolerance, the resultant humidity formula calculation differs by 8.8% points! If a lookup table is used instead of a formula calculation, the difference might be even greater. This error is greatest in the wet/dry-bulb calculations at very low and very high RH.

The RH also can be read directly from a hygrometer or continuously recorded with a hydrograph.

A surface temperature thermometer like the one shown in Figure 3 uses a bimetallic sensing element. It can be magnetically attached to a steel surface, and tape will hold it to other surfaces.

Thermometers should remain in place for a sufficient period of time for the temperature to stabilize—typically 2 or 3 min. Tap the dial lightly before taking a final reading, and take care to read straight-on. Avoid direct sunlight, wind, thermal radiation, heating or ventilation ducts, or other such conditions. Obtain data for hot and cold areas as well as for average areas.

Digital, noncontact infrared thermometers also can be used to measure surface temperature. Read the instrument’s instructions carefully. The further away from the surface the device is held, the larger the area of measurement is—causing potential error.

### ELECTRONIC MEASUREMENT DEVICES

Atmospheric conditions are always changing; therefore, measurements and calculations should be made fre-

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**TABLE 1**

<table>
<thead>
<tr>
<th>Dry (°F)</th>
<th>Wet (°F)</th>
<th>RH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.5</td>
<td>73.5</td>
<td>95.4</td>
</tr>
<tr>
<td>75.0</td>
<td>73.0</td>
<td>90.9</td>
</tr>
<tr>
<td>75.5</td>
<td>72.5</td>
<td>86.6</td>
</tr>
</tbody>
</table>

A 1/2-degree difference results in a calculated difference of 8.8 percentage points.
quently. Four hours is a typical minimum period. It is recommended that different locations be measured and conditions recorded before, during, and after the job. Some specifications call for continuous monitoring while abrasive-blast-cleaned steel is exposed or while coatings or linings are curing; continuous monitoring ensures that the metal is warmer than the dew point.

Some meters calculate dew-point temperature only, but the more practical instruments have an attached surface temperature probe (Figure 4). A probe allows a meter to calculate and display the important delta value—the difference between the surface and dew-point temperatures.

Continuous monitoring is one reason why digital, all-in-one instruments are quickly becoming popular. They greatly simplify the process of measuring and calculating critical environmental parameters. Fast-response precision sensors provide accurate, repeatable readings with high reliability and long-term stability. Certificates of calibration showing direct traceability to National Institute of Standards and Technology standards usually are available.

Some digital instruments continuously and simultaneously display all five environmental parameters on the liquid crystal display (Figure 5). Not only are the values displayed, but they can be stored in the gauge’s memory at the press of a button along with the date and time. Better yet, input a time interval and the gauge can be left unattended to record all five values at that interval—say, every 15 minutes or every hour. This is handy for keeping a complete record of environmental conditions leading up to, during, and after application of the coating.

All-in-one instruments usually provide higher accuracy, greater simplicity, and faster response than mechanical methods. Their easy, one-handed operation is handy when climbing a ladder or scaffold or when reaching distant locations and small, hard-to-reach areas. Output on the display is fast and continuous.

Another advantage that digital instruments provide is that they take much of the guesswork out of measuring. Many models have alarms that automatically alert the user when the surface temperature is too close to the dew-point temperature; this feature signals the high risk of moisture formation. Most display in both Celsius and Fahrenheit units. Some record the surface temperature value only after that value has stabilized. In other words, touch a cold or hot surface and the instrument will monitor the temperature reading as it drops or rises to the actual surface temperature. In a few seconds, once the gauge determines that the reading has stabilized, it beeps and freezes the display. This is particularly handy when measuring remote areas where the display is difficult or impossible to view.

References

DAVID BEAMISH is General Manager of DeFelsko Corp., 802 Proctor Ave., PO Box 676, Ogdensburg, NY 13669. He has a degree in civil engineering and has more than 15 years’ experience in the design, manufacture, and marketing of handheld coating test instruments in a variety of international industries, including industrial painting, quality inspection, and manufacturing. He conducts training seminars and is an active member of various organizations including NACE, ASTM, and ISO.