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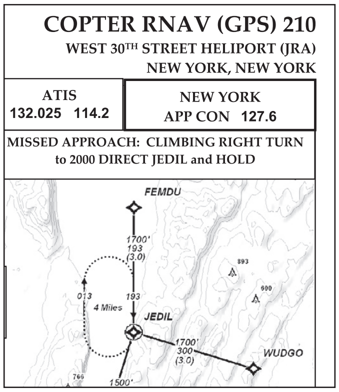
Listen up for the new kid on the block ... page 6

Gone TU ... page 15



A novel approach ... page 13

ALSO INSIDE THIS ISSUE ...

USING THE SKEW-T LOG (P)

Once you untangle yourself from all those squiggly lines, you'll find the footprints of cloud layers, fog, turbulence, and ice.

by Scott C. Dennstaedt

I am continuously bombarded with questions about the Skew-T log (p) diagram. It seems that pilots are frantically looking for any internet references or books that explain how to read this gem of a tool. The good news is that there is a plethora of tutorials on the web that provide a broad-brush overview. The bad news is that none teach a pilot how to *apply* the diagram in the context of aviation weather.

That skill is too long to cover in-depth in something as short as an article. (I recently released my own training CD that does cover this in depth and is specifically tailored for pilots.) What I can do, however, is show you some specific examples of how the Skew-T can help pinpoint adverse weather in the making. Given that adverse weather has many faces, you'll need to distinguish between dozens of different signatures when examining the diagram. It's paramount that this be done in the context of other forecasts and observations.

This article picks up from "Reading a Skew-T" (March 2008 *IFR*), and you might want to go back and review the meaning of the lines on the base thermodynamic diagram and parcel theory.

Cloud Formation

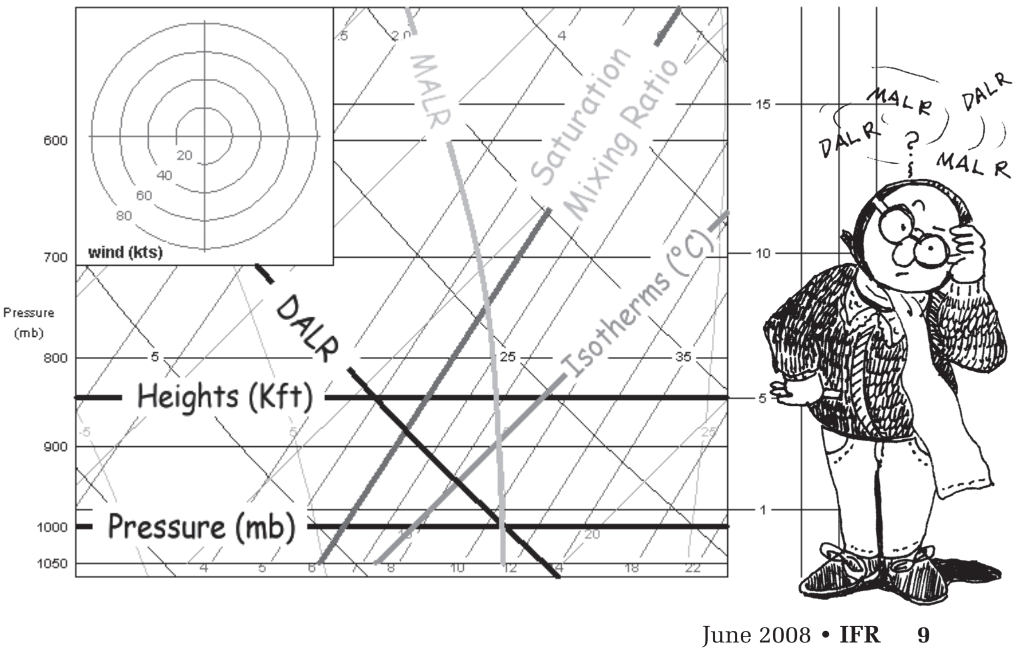
One of the most useful applications of the Skew-T diagram is seeing where to expect clouds, something that's especially important with potential icing. Clouds come in two basic flavors: vertically-developed, such as cumulus clouds, or stratified. A combination of both, called stratocumulus, is also possible.

Without the dewpoint "fold-over," shown on the Skew-T, radiation fog doesn't have a chance to form.

Here's a quick review of cloud formation: Convection usually forms clouds when moisture is coupled with daily heating or large-scale movement of air masses. The rising air can produce cumuliform clouds, which can grow into cumulonimbus clouds under the right conditions. Advection—movement of air via wind—can form clouds, such as when cold air or moist air moves into an area and produces stratiform clouds or when air rising with terrain creates clouds by a mountain range. Radiational cooling, such as on a clear and calm night, might cause the temperature in the first 1000 feet of the surface to fall to the dewpoint producing reduced visibilities, low stratus or even fog. This can be enhanced by advection.

The dewpoint depression, what is commonly called the temperature-dewpoint spread, on the Skew-T diagram can help identify stratiform clouds. When the dewpoint depression is zero (relative humidity is 100 percent), the air is said to be saturated. Saturated air does not, necessarily, mean clouds exist, but locating saturated or nearly-saturated conditions on a Skew-T diagram is a reliable way to isolate stratus cloud tops and stratus cloud bases with some important exceptions.

If the temperature and dewpoint on the Skew-T diagram come together at 3000 feet and diverge at 6000 feet, there's a high probability of an overcast cloud deck between 3000

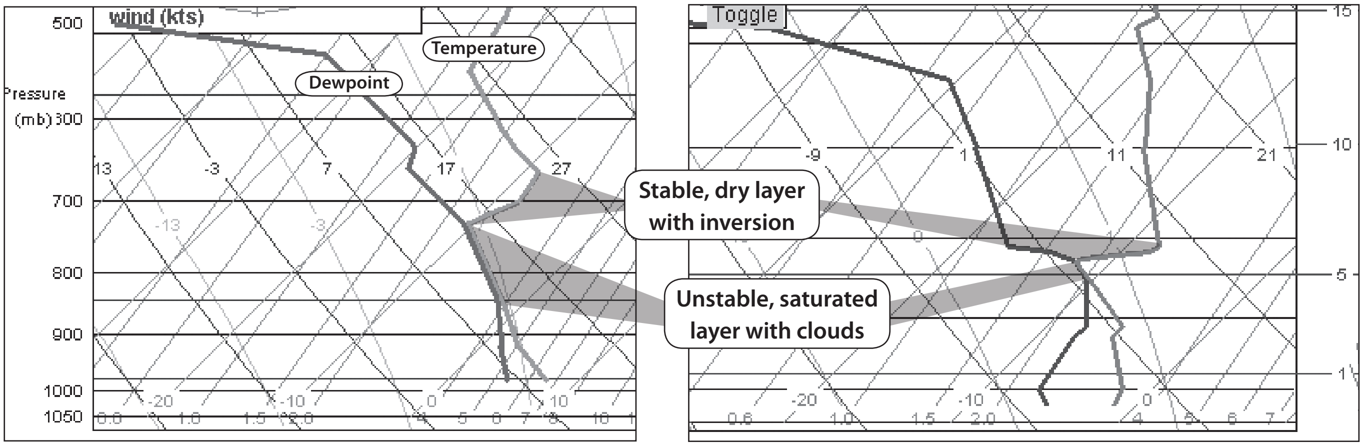


Right: In case you missed the memo, here's the quick key for the Skew-T lines. Altitudes can be read by pressure on the left of the box or pressure altitude on the right. DALR is the dry adiabatic lapse rate. MALR is the moist adiabatic lapse rate. Temperatures are read where the squiggling lines showing actual temp or dewpoint (not shown on this chart) cross the isotherms. Wind speed and direction get plotted on the far right (behind Hal).

SKEW-T SLEWTHING MEANS LEARNING SIGNATURE PATTERNS

Without a degree in meteorology, you'll be hard-pressed to look at the Skew-T and analyze the data to predict what you'll see on the actual flight. But you can learn to watch far certain signature patterns that often accompany weather you'd like to avoid. Here are four patterns you can look for when you're searching for more insight on what to expect en route.

THE ICE CHEST: SATURATION BELOW AN INVERSION

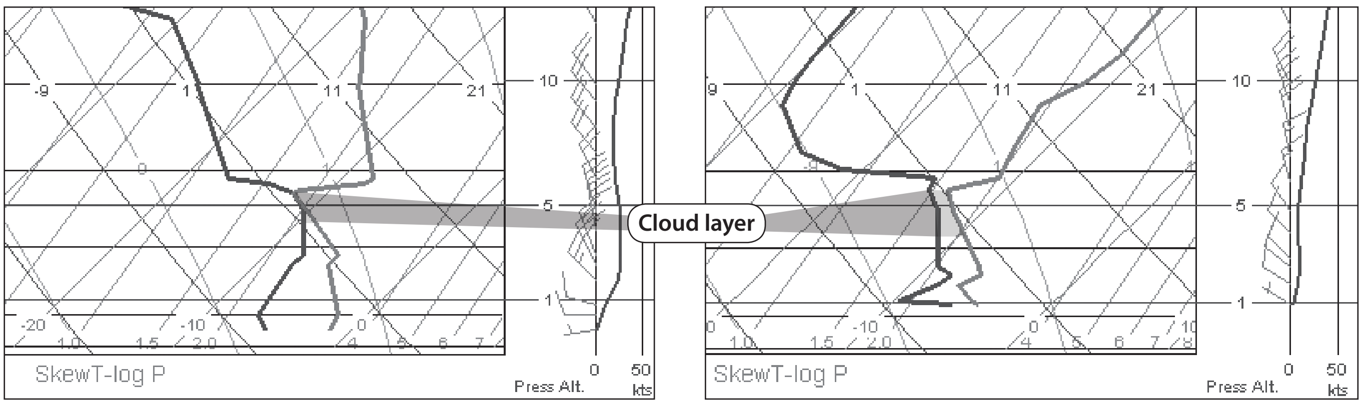


Stratocumulus clouds have a distinct signature on the Skew-T diagram. The first thing to notice is the distinct temperature inversion representing a stable and dry layer immediately above the clouds, which acts as a cap or lid. The inversion is fairly pronounced for the diagram on the right, with a four-degree temperature increase within 500 feet. The inversion on the left diagram isn't as strong, but it's still a significant cap.

The next thing to notice is the saturated layer or cloud layer below the inversion. When the temperature profile in the saturated layer is unstable or nearly the same as the moist adiabatic rate, as it is in both soundings, you can expect more liquid water content in these clouds—especially at the tops. It is also typically unstable in the dry air below the cloud deck as well, with lapse rates normally approaching the dry adiabatic lapse rate.

Instability near the surface with unstable air in the clouds capped by a temperature inversion is the classic signature for stratocumulus clouds. Add temperatures in the -2 degrees to -15 degrees C range and you've got a recipe for a nasty icing encounter even for a thin layer of stratocumulus.

SUCKER-HOLE SIGNATURES: LINES THAT DON'T QUITE MEET



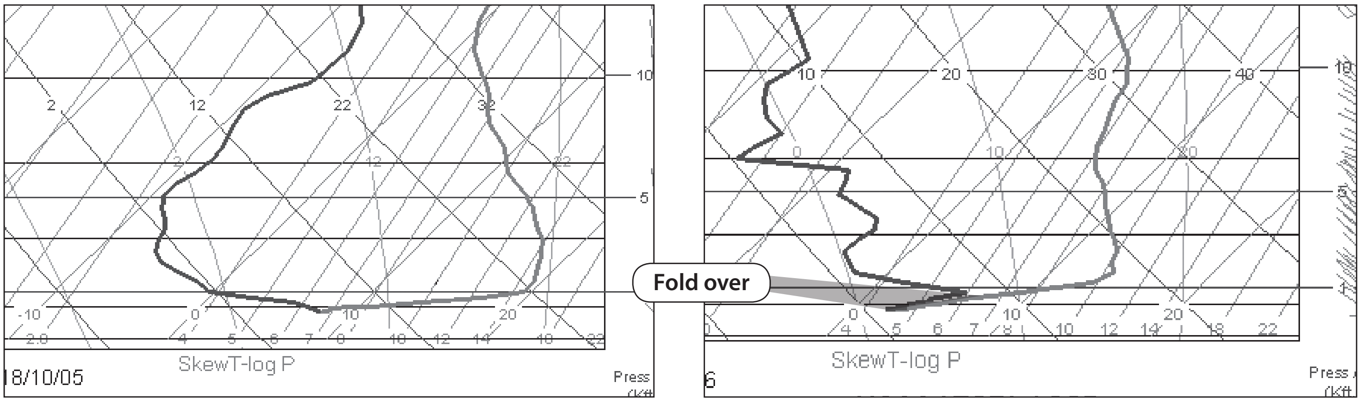
KAPG 161155Z 27005KT 7SM OVC050 M01/M03 A3023

KPIT 161051Z 26004KT 7SM -SN SCT012 BKN035 M04/M07 A3025

For a cloud to form, the air must be super-saturated, meaning a relative humidity slightly greater than 100 percent. That usually equates to a a dewpoint depression of zero in the cloud deck. On the left, a rawinsonde observation (RAOB) from the Aberdeen Proving Ground, Md., (KAPG) shows a thin saturated layer around 5000 feet. So does the KAPG METAR.

On the right, a RAOB from Pittsburgh, Pa., (KPIT) does not have the same saturated layer, but does show a small dewpoint depression of a degree or less that corresponds to the broken sky reported at Pittsburgh. The balloon could have ascended through a hole and never really entered a cloud or simply brushed by the edge of a cloud.

A BLANKET OF FOG: BEWARE THE FOLDOVER

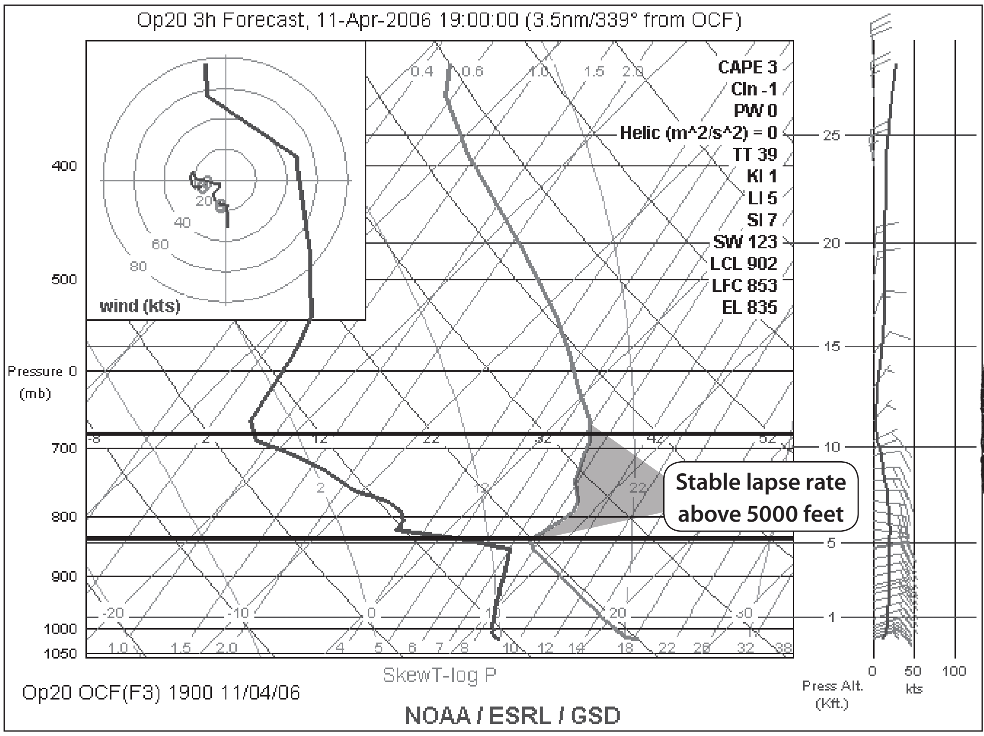


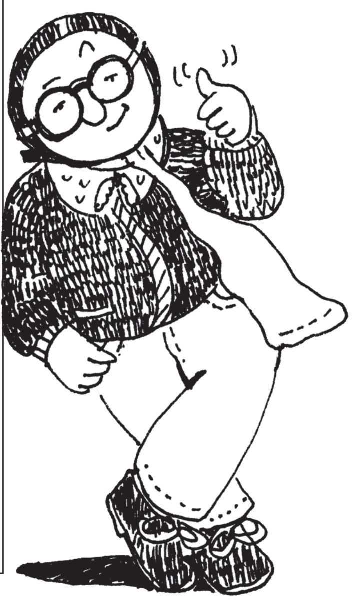
Many pilots are taught that if the temperature and dewpoint are the same at the surface, fog will form. Unfortunately, it's not that simple.

Both these soundings exhibit a strong nocturnal temperature inversion. The left-hand sounding from Raleigh-Durham, N.C., (KRDU) shows the temperature and dewpoint are equal at the surface, but the dewpoint quickly decreases with height. This limits the chance of fog.

The sounding on the right from Washington, D.C., (KDCA) shows a dewpoint increasing with height essentially folding over the temperature inversion near the surface. This produced a dense radiation-fog event.

FINDING THOSE HEAD-BANGING ALTITUDES: LINES LEAN LEFT IN THE WIND





In this three-hour Rapid Update Cycle (RUC) forecast for Ocala, Fla., (KOCF), all three elements of thermal turbulence are present.

There's an unstable environmental lapse rate—the right-hand solid line representing temperature is leaning far to the left—from the surface through 5000 feet. Skies are generally scattered to broken cumulus with plenty of insolation. Winds are 15 to 20 knots in the unstable layer.

These ingredients will produce moderate thermal turbulence below 5000 feet. Flying at 8000 to 10,000 feet should put you well above the top of the cumulus clouds and into smooth air.

and 6000 feet. If the temperature and dewpoint come within a degree of each other over this same range of altitudes, but never touch, expect broken to overcast clouds. Larger dewpoint depressions may imply a broken or scattered layer.

Realize that if you're looking at a Skew-T built from rawinsonde data, these are conditions in the past. Pilots are inherently interested in what might happen in the near future, but predicting humidity in time and space is a challenge. The best we can do is look at the forecast dewpoint depression and begin to suspect the potential for clouds or layers whenever the dewpoint depression is approaching zero.

Just to keep you honest, it's common to have cloud-free air in the first one or two thousand feet of the surface even with small dewpoint depressions (e.g. rain falling from the base of a cloud). Also, when the temperature is below -15 degrees C, the dewpoint becomes less valid since the air may be saturated with respect to ice, rather than water. The "frost point" might be a better indicator for cold stratus clouds (but not always). Unfortunately, it's not plotted. Significant clouds could be present with a dewpoint depression as large as three or four degrees C when the temps are that low.

Cumuliform Clouds

Cumuliform clouds are formed through saturation due to adiabatic expansion (rising air), and don't follow the same rules with respect to the Skew T. For now, we won't worry about the causes of rising air, but instead, let's examine what happens to air as it ascends.

As unsaturated air ascends, it expands and cools at the dry adiabatic lapse rate (DALR), which is three degrees C for every 1000 feet gain in altitude. Insolation (heating of the earth's surface by the sun) causes a pocket (parcel) of air at the surface to become slightly warmer than the surrounding air, allowing it to freely ascend (positively buoyant). The parcel will continue to ascend as long as its temperature is warmer than the surrounding air.

If the environmental lapse rate near the surface is sufficiently large enough, the heated air parcel will remain positively buoyant, continue to rise and, possibly, reach saturation. This is how most "fair-weather" cumuliform clouds are formed. If the parcel is too dry at the surface, it never has the chance to saturate during its short ascent.

Temperature Inversions

Temperature normally decreases with height, but with an inversion, temperature increases with height. Several processes can cause this but an especially important one is radiational cooling at night, which is the leading producer of dense fog.

A dewpoint depression of zero at the surface alone won't produce fog; reduced visibility may ensue, but not fog. There must be little or no turbulent mixing and a favorable hydrolapse for fog. A favorable hydrolapse occurs when the dewpoint increases with increasing altitude. On the Skew-T, the dewpoint essentially "folds over" the temperature. Without this fold over, the radiation fog doesn't have a chance to form.

Turbulence

Thermal turbulence is probably the most common form of turbulence we experience and is rarely covered by AIRMET Tango. In clear air, thermal turbulence is rarely severe and has three basic ingredients. First, to produce the thermals, it requires insolation near the surface. Second, a large

(continued on page 22)

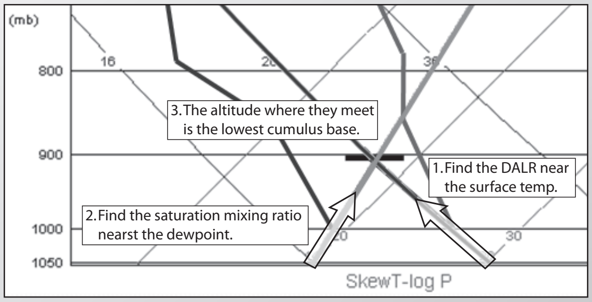
CUMULUS CLOUD BASES: A TOUGHER NUT

Finding the bases of cumulus clouds takes more than simply seeing where temperature and dewpoint meet. Here's what you need to do.

Assume the temperature and dewpoint of an air parcel start out the same as the temperature and dewpoint of the environment. (In reality, the parcel temperature is usually a bit warmer). On this chart, the parcel would start at 26 degrees C and the dewpoint at 19 degrees C. This parcel starts out unsaturated because the temperature and the dewpoint are not equal at the surface. If we lift this unsaturated parcel, it will expand and cool dry-adiabatically. That means the temperature inside the rising parcel will decrease at 3 degrees C for every 1000 feet gain in altitude.

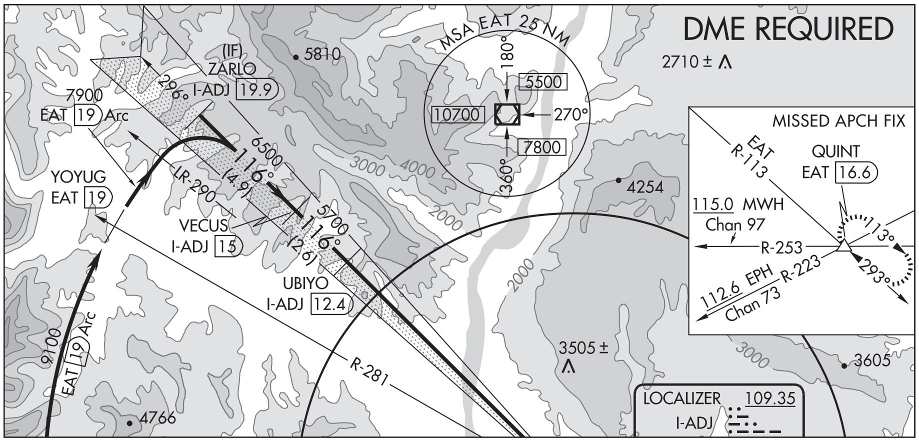
Find the closest DALR line to the surface temperature. The closest line is conveniently right at the surface temperature of 26 degrees C. By following this line up and to the left, the temperature is decreasing at the DALR, which helps us predict the temperature of the parcel as it ascends.

The dewpoint temperature within the rising parcel changes as well. It changes at a rate defined by the saturation mixing-ratio. The same method applies: Find the closest saturation mixing-ratio line to the surface dewpoint temperature. In this case, the closest line conveniently exists right at the surface dewpoint temperature of 19 degrees C. We follow this line up and to the right until it crosses the dry adiabatic line we traced already. If lifting continues to this level, saturation will occur at the altitude where these two lines meet. Here that's at 900 mb, or about 2000 feet.



This is called the lifted condensation level (LCL) and represents how far air needs to be lifted to produce cumuliform clouds. Effectively, the LCL identifies the convective cloud bases.

—S.D.



***Left:** Even without flying the arc, identifying VECUS on this approach to Wenatchee, Wa. (KEAT) requires DME. So, the plan view gets a note.*

though, there would be a note in the plan view. In addition to FAA order 8260.3 (the TERPS manual) paragraph 161, equipment requirements are also identified in FAA Order 8260.19 paragraph 855h:

"(1) Where certain equipment is required for procedure entry from the en route environment, enter the following in the Additional Flight Data: 'Chart planview note: ADF REQUIRED,' or 'ADF OR DME REQUIRED.'

(2) Where other navigation equipment is required to complete the approach, e.g., VOR, ILS, or other non-ADF approaches requiring ADF or DME for the missed approach, use: 'Chart note: ADF required,' or 'Chart note: DME required.' When radar vectoring is also available, use: 'Chart note: ADF or Radar required.' "

That latter item—"or Radar required"—comes up as a question too. Does this mean that you can fly the approach without DME if ATC agrees to call the fix for you? Yes, that's exactly what it means.

Mistakes Were Made

But PATYI doesn't offer radar as an option, so how are you supposed to identify it? We have some good friends in Oke City who have yet to tire with our questions about specific approaches. (All IFR readers owe a round of thanks to Brad Rush at the National Flight Procedures Office for handling the bulk of this.)

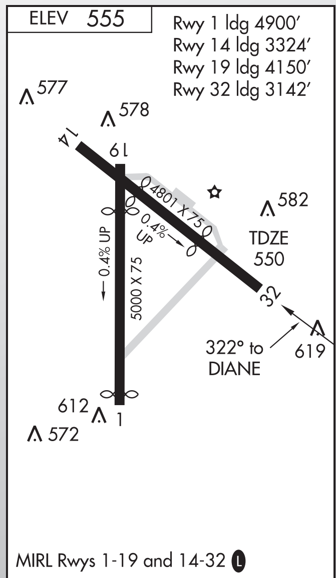
It turns out the approach does require DME. And now, as a direct result of IFR's meddling questions, you can look at "FDC NOTAM 8/2997 SJC … ILS OR LOC/DME RWY 30L, AMDT 22A," and after a bunch of changes to DAs and MDAs, you'll find this little tidbit: "NOTE: DME REQUIRED."

QUIZ ANSWER *(question on page 14)*

This one falls into the "Be Careful What You Ask For" category. Orange Municipal (KORE) got a new GPS approach for Runway 32. When this happened, the airport obstructions were surveyed.

The catch is that survey checks for obstructions based on a particular category of aircraft. Unfortunately for KORE, they qualified for an obstruction clearance of 40:1 and a bunch of trees off the airport property on both ends cut right into that slope when the surveyor stood at the threshold. We were told by the airport manager that the surveyor just started backing up—1500 feet worth of backing up—until the sight through his transit didn't include trees.

The result was 4800 feet of pavement with about 2000 feet available for landing. Lucky for Orange, they are getting reclassified to an approach slope more appropriate to a small, uncontrolled field. Once the new paint dries, the displacements should be back to a more reasonable 800 feet or so on either end.



USING THE SKEW-T

continued from page 12

lapse rate is required to allow the thermals to rise. Third, the prevailing wind in the unstable layer must be of sufficient strength. Sounds like a perfect match to diagnose on the Skew-T diagram.

During the warm season, most of the thermal turbulence we experience is during the afternoon and early evening hours within the first four or five thousand feet of the surface, also known as the boundary layer. In the morning, the lapse rate is generally small, producing a stable environment with little or no turbulence. As insolation increases throughout the day, the surface temperature begins to increase as does the temperature of the air in the boundary layer. This surface heating produces an environmental lapse rate equal to the DALR. If the winds are generally strong (10 to 25 knots), moderate thermal turbulence will result.

Scan the Skew-T diagram for any lapse rates approaching the DALR and look for strong winds. This combination may not result in a turbulent layer, but it should get your attention. If possible, plan a flight that minimizes your exposure to this layer. If the environmental lapse rate is small, the winds are light or there's an overcast sky, thermal turbulence can be eliminated.

So the goal is to find an altitude on the Skew-T diagram that exhibits a small or negative lapse rate. A small lapse rate caps the rising thermals and limits or eliminates thermal turbulence even with relatively high winds near the surface.

Icing Potential

The first order of business with icing is to locate the freezing level to see if you can just stay below the ice. Identifying the actual or predicted lowest freezing level is easily accomplished by using a Skew-T diagram. The lowest freezing level is found by looking for the point where the environmental temperature crosses over the zero-degree C isotherm.

Freezing rain is normally found when multiple freezing levels exist within a deep layer of saturated or nearly saturated conditions. In the classical case, the temperature at the surface is at or below freezing. This shallow freezing layer is capped with temperatures above freezing (the inversion), which is called a warm nose on the Skew-T. Above the warm nose, the second freezing level exists with saturated conditions aloft. Icing potential is likely above and below the warm nose.

With the freezing level in hand, it's not terribly difficult to evaluate the threat of icing using a Skew-T diagram. Structural icing is possible when the environmental temperature falls between 0 degrees and -25 degrees C when combined with small dewpoint depressions. While there are no easy rules here, a smaller dewpoint depression indicates a greater probability for icing in clouds when the temperature is between -2 degrees and -15 degrees C.

By combining the temperature and dewpoint profile on the Skew-T diagram with the operational forecasts and current observations, you can get a comprehensive picture of the icing potential. Keep in mind that as the temperature drops below -15 degrees C, the air is saturated with respect to ice, not liquid water; so the dewpoint depression will be one or two degrees even though the air is saturated.

Stratocumulus clouds are notorious for being benign-looking, but they can pack a punch when it comes to icing. These clouds often extend over large distances, like stratus clouds do, but the temperature profile within them is rather unstable, like cumulus clouds, so they can produce a good bit of liquid water. The big difference between these clouds and cumulus is that stratocumulus are strongly capped by a temperature inversion, keeping them from becoming more than a few hundred to a few thousand feet deep in most cases.

If the temperature profile is right, this means that the top of the stratocumulus deck will stay well within the icing temperature range and can be a candidate for having copious amounts of supercooled liquid water. It's usually pretty close to the top, which also tends to be where the temperatures are the coldest in these layers. That can pose an ugly combination for icing.

Still More to Learn

The presence of clouds, temperature inversions, turbulence and icing potential are just a few of the uses of this great chart. This diagram also plays a key role in predicting convective outbreaks, but that, and many of the other signatures of the Skew-T, are a discussion for another time.

Similar to what I recently discussed in April *IFR* (A Strategy For Weather Savvy), take some time and try to compare the Skew-T diagram at http://rucsoundings.noaa.gov to the weather reports and forecast such as METARs, TAFs and PIREPs. If you still have trouble discovering the magic behind this tool, feel free to send me an e-mail at scott@chesavtraining.com.

Scott Dennstaedt is an IFR *contributing editor. His website is www.chesavtraining.com.*