In some operating areas, the change in ambient temperature from day to night can exceed 50°F. This cyclic temperature change can cause false pressure responses in low-quality pressure gauges and significant pressure responses in the wellbore.

A large number of diagnostic fracture injection tests (DFITs) have proved difficult or impossible to analyze because of cyclic pressure changes. These test failures are often attributed to the thermal response of the surface pressure gauge to changes in ambient temperature or to the use of small-diameter capillary tubing to connect the pressure recorder to the well.

This article will show that the daily pressure cycling continues even when a thermally compensated dual-quartz crystal pressure gauge for acquiring surface pressure data is used. It will also show that the use of small-diameter capillary tubing to connect the pressure recorder to the wellhead has no effect on data quality.

It will be shown that the effect of daily pressure cycling can be significantly reduced by insulating the wellhead and using injection fluids with low thermal expansion.

A DFIT is used to determine reservoir characteristics such as minimum in-situ stress, permeability, and reservoir pressure. It is conducted by pumping a small volume of fluid, typically from 10 to 20 bbl, into the formation to fracture the rock and extend the fracture a short distance into the formation. After the fluid is pumped, the well is shut in and the decline in pressure is recorded from the wellhead. When DFITs are performed on conventional wells with rock permeability exceeding 0.01 md, a pressure decline of hundreds of pounds occurs over 1 day to 2 days.

In unconventional reservoirs, the permeability ranges from less than 0.01 md to the nanodarcy level. The pressure decline can take weeks or months to reach the flow regime needed to determine permeability and reservoir pressure. Because of the time required for the test, the daily reservoir pressure decline is of the same magnitude as the pressure change caused by thermally induced pressure fluctuation in the wellbore fluid. However, this data cannot be analyzed because the “noise” is of the same magnitude as the “signal.”

The link between the cyclic pressure changes and ambient temperature changes has three possible sources, more than one of which can be present at the same time. They are

- Thermal compensation of the pressure recorder
- Thermal expansion/contraction of the fluid in the wellhead
- The use of capillary tubing to connect the pressure recorder to the wellhead

**Thermal compensation of recorder.** Because of the need to gather a superior quality of data from a DFIT, operators have used dual-quartz pressure transducers for recording the test results. These highly accurate transducers can be calibrated to compensate for the effects of ambient temperature change. Without calibration to compensate for the temperature effect on the pressure sensing element, the pressure readings will be inaccurate.

When tested in a laboratory, the output pressure response from a quartz crystal decreased from 5,250 psia to 4,950 psia as temperature was increased from 40°F to 115°F and the applied pressure was held constant at 5,050 psia. Further testing of the quartz crystal has shown that as the pressure increases, the magnitude of the effect caused by a 1°F change in temperature also increases.

For gauges with ineffective thermal compensation, the effect will be present but reduced. The result could manifest itself as cyclical behavior observed on unconventional DFITs.

Based on an understanding of the nature of pressure transducers, ambient temperature effects on the pressure gauge could be the root source of the cyclic pressure response problem. If this is the case, it is important to remember that only the surface data would be affected by ambient temperature changes. Data acquired from downhole gauges would be unaffected because of isothermal conditions.

**Thermal expansion/contraction of fluid in wellhead.** During a DFIT, the wellbore must be full of fluid. Typically a 2% to 4% KCl-water mixture, the fluid is subject to thermal expansion and contraction as the wellhead heats and cools from day to night. When the fluid expands or contracts inside the closed volume of the wellhead, a corresponding increase or decrease in pressure results.

Fluids with a higher coefficient of thermal expansion will expand the most. As the fluid is trapped inside the closed volume of the wellhead, the pressure will increase when the fluid is heated. The amount of the pressure increase depends
on the bulk modulus of elasticity (the inverse of compressibility). Thus, the ideal fluid is one with a low coefficient of thermal expansion and a low bulk modulus of elasticity.

Because the wellhead is hydraulically connected to the reservoir, the cyclic pressure response from the expansion and contraction of fluid inside the wellhead should be detectable in a bottomhole gauge (BHG) and in the transducer at the surface. If the cyclic pressure response is caused by the calibration of the transducer, then the effect should not be detectable in a BHG.

Fig. 1 is a plot of dual-quartz pressure gauges at the surface (blue curve) and in the bottomhole zone (red curve). Only the surface gauge detects the daily temperature swings. The green line shows the temperature inside the surface recorder and the thick black line shows the BHG temperature.

The cyclic pressure response can be seen on both the surface and bottomhole pressure recorders. The BHG is isolated from daily temperature cycles at the wellhead, yet it mirrors the surface gauge. These results confirm that the source of the cyclical pressure fluctuations in a long-term DFIT is the thermal expansion and contraction of the fluid in the wellhead and not the surface gauges with inadequate thermal compensation.

Use of capillary tubing to connect pressure recorder to wellhead. The surface pressure data in Fig. 1 was acquired using a pressure recorder connected to the wellhead by 20 ft of 1/16-in. diameter capillary tubing. It is apparent that the use of capillary tubing has no deleterious effect on the quality of data.

Reducing the Effects
To minimize the cyclic pressure responses caused by the expansion and contraction of the fluid inside the wellhead, the changes in ambient temperature need to be reduced. The rate of temperature change of the wellhead fluid can be reduced by insulating the wellhead. Insulation will shield the wellhead from direct sunlight, reduce radiation emission to the night sky, and dampen ambient temperature changes.

Fig. 2 is a comparison of two wells that experienced ambient temperature changes greater than 30°F. Well A (red curve) was insulated while Well B (blue curve) was uninsulated. The ambient surface temperature (dark green line) taken by the surface pressure recorder cycles every 24 hours between nighttime lows and daytime highs.

The ambient temperature had a more pronounced effect on the uninsulated well. Although the insulated well has a measurable response to ambient temperature changes, the insulation has reduced the magnitude of the response.

When this data is imported into the DFIT analysis software as shown in Fig. 3 and plotted on the log-log of Nolte G time vs. delta surface pressure, the derivative of pressure with respect to G function (the G dP/dG curve) shows that the ambient temperature changes cause noise in the G dP/dG curve. The selection of closure time and the identification of flow regimes are ambiguous.

However, when the data from the insulated well is compared with the uninsulated well, the G dP/dG curve shows the ambient temperature effects have been reduced by the wellhead insulation. The closure time and after-closure flow regimes are clearly identifiable, thus providing greater confidence in the after-closure analysis.

Conclusions
Cyclical pressure fluctuations during DFITs have been shown to result primarily from fluid expansion in the wellhead because of ambient temperature changes. They are

1. Pressure responses caused by ambient temperature changes
are seen on both surface and bottomhole gauges. Therefore, the observed cyclical pressure fluctuations are real and not the result of poorly thermally compensated pressure gauges or the capillary tubing occasionally used to connect the pressure recorder to the wellhead.

2. Ambient temperature effects on pressure decline can be considerably reduced by insulating the wellhead.

3. Selection of fluids with low thermal expansion can reduce cyclic pressures caused by changes in ambient temperature. **JPT**

Fig. 2—The pressure curves in wells with insulated and uninsulated wellheads are shown with the fluctuation in surface temperature.

Fig. 3—A diagnostic fracture injection test analysis shows the comparison of surface pressure in two wells with uninsulated and insulated wellheads.