Platform Express equipment hanging in the derrick and ready to go downhole in Bakersfield, California, USA. In this region of 1200-ft [360-m] wells, reductions in rig time and rathole are cutting logging costs 20 to 30%. New measurements and answer products are leading to better detection of bypassed pay and more efficient steamdrive strategies.
A First Look at
PLATFORM EXPRESS Measurements

For more than 20 years, the triple combo has provided fundamental formation evaluation in wells worldwide. Now the next generation of wireline technology has arrived, addressing industry’s growing demand for diverse, high-quality data and greater operational efficiency.

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Low oil prices over the last decade have forced a steady improvement in the efficiency of oilfield operations. This efficiency continues to evolve in two ways—gradually, like a river continuously reshaping its course, and suddenly, like a river overflowing and cutting a new channel that redirects its course. Every so often, an abrupt jump in efficiency comes from a new technology that increases productivity. In wireline logging, the latest catalyst of such a leap is the recently introduced PLATFORM EXPRESS technology—a wireline instrument that addresses the industry’s demand not only for efficiency, but also for improved reliability, flexibility and accuracy (previous page).

The PLATFORM EXPRESS name explains the technology’s most striking departures from convention. Platform because multiple functions are integrated into a single package and sensors are interlaced on the same sonde, rather than assembled as a series of separate, connectable units. As a result, the measurement package is less than half the length of a conventional triple combo—38 ft [12 m] versus 90 ft [27 m]—and, at 690 lb [311 kg], about half the weight (below and right). Express because nearly (continued on page 7)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Triple combo</th>
<th>PLATFORM EXPRESS</th>
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<tbody>
<tr>
<td>Length, ft (m)</td>
<td>typically 90 (27)</td>
<td>38 (12)</td>
</tr>
<tr>
<td>Weight, lbm (kg)</td>
<td>1500 (675)</td>
<td>690 (311)</td>
</tr>
<tr>
<td>OD, in.</td>
<td>3 3/8 to 4 1/2</td>
<td>3 3/8 to 4 5/8</td>
</tr>
<tr>
<td>Temperature rating, °F (°C)</td>
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<td>250 (120)</td>
</tr>
<tr>
<td>Pressure rating, psi</td>
<td>20,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Max logging speed, ft/hr (m/hr)</td>
<td>800 (540)</td>
<td>3600 (1080)</td>
</tr>
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Light is good, short is better. The shorter length and lighter weight of PLATFORM EXPRESS equipment (right) compared to the conventional triple combo logging string are made possible by integration of sensors and telemetry equipment. Specifications of this technology allow it to be used in 90% of operations worldwide.

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A sample of PLATFORM EXPRESS presentations.

Track 1: Conventional track 1 data, including a water saturation, \( S_w \), calculation. Gamma ray backup is used to find zones that are more radioactive than normal. Typically, the backup is scaled 100 to 200 API units when the track is scaled 0 to 100 units.

Track 2: Calculated micronormal and microinverse curves, from the microresistivity measurement. Separation (arrows) is a qualitative permeability indicator since it occurs in front of mudcake, which accumulates at permeable intervals.

Track 3 and 4: AIT Array Induction Imager logs, comparing 90- and 10-in. resistivity readings with the 4-ft vertical resolution 90-in. conductivity reading and the microresistivity log. Conductivity can be easier to read when values reach extremes, and is helpful in making comparisons to old logs. Track 4 shows all five depths of investigation for the induction log and \( R_w \) with an 18-in. [45-cm] vertical resolution for easier comparison with induction measurements. Vertical resolution of the \( R_w \) measurement can be as good as 1 in.

Track 5: Real-time resistivity-derived dip from the PLATFORM EXPRESS laterolog (red) and FMI Fullbore Formation MicroImager measurements (black). The two tracks of densely spaced color stripes are laterolog-derived images. The first image is the second derivative of the log curve, in which color changes indicate bed boundaries that are used to compute dip. The next image is normalized to show bedding. These images help estimate structural dip trends.

Comparison of logging time expenditure before and after initiation of PLATFORM EXPRESS services (left) and rig time comparison of triple combo versus PLATFORM EXPRESS services averages for land and offshore wells (right). In the Phillips-Schlumberger alliance in the Texas Panhandle, average time in hole with conventional logging was 9.5 hours and with PLATFORM EXPRESS equipment 3.7 hours, a savings of 5.8 hours in rig time per well. "Once the logging tool is on bottom, we know within minutes if we're going to set pipe," said Mark Bowman, a geologist with Phillips, "whereas before, we had another 6 to 8 hours of logging before we'd even begin printing the logs." Some operators have achieved greater time savings by using PLATFORM EXPRESS log quality measurements to justify elimination of routine repeat sections.
all operations take less time (previous page, top). Shorter tool length saves time drilling rat hole and in rigging up and down; new technology speeds calibration and doubles logging speed; faster, more comprehensive real-time data processing reduces turnaround time and provides answers previously unobtainable at the wellsite.

During the initial commercialization of PLATFORM EXPRESS, reliability was five times that of conventional technology, mainly due to shock-resistant designs adapted from logging-while-drilling equipment developed by Anadrill (right). Greater flexibility is both literal and figurative. Two hinge joints combined with the shorter 38-ft length allow more successful logging of higher angle holes and provide new opportunities to log the increasing number of short-radius wells.

The articulated pad, which is also shorter than previous designs, improves sensor positioning to provide better data in rough holes. Coupling this new service with the high-efficiency MAXIS Express surface system provides data in formats that can be configured to diverse markets—from the most cost-sensitive to those demanding the most comprehensive and accurate information (previous page, bottom and below).

For drillers, flexibility, efficiency and reliability all contribute to higher productivity. But perhaps the most significant advance-

Track 6: Lithocolumn display, at 1:1300, a scale geologists use for correlation. The left track is a laterolog-derived image that shows the degree of bedding. Light is low-resistivity contrast and dark is high. The right track, in which the right margin of the track is effective porosity and the left is bounded by the gamma ray log, shows lithology.

Track 7: A resistivity invasion profile, 90 in. from the center of the borehole, in which red is high resistivity and blue is low.

Track 8: A laterolog-derived image, in which light bands are resistive and dark are conductive. This image is used mainly for bedding identification and correlation, but can also be used for dip analysis on a workstation. The white trace represents the path followed by the high-resolution pad.

Track 9: Log quality control (LQC) output. The seven stripes to the left of the induction log are LQC tracks for resistivity measurements. Each stripe represents a parameter. The five stripes to the left of the nuclear track are five parameters for the nuclear log and accelerometer, including accelerometer, density hardware, neutron porosity correction, density processing and photoelectric factor processing checks. A flag appears in the green tracks if any critical parameters exceed predetermined values.

Track 10: $R_i$ and mud resistivities from induction and laterolog measurements, and invaded zone microresistivity, filtered at 18 in.

Track 11: Environmentally corrected neutron porosity and a standard-resolution density porosity. Although not shown here, the density reading has been computed at resolutions as good as 2 in. (5 cm).

Track 12: A lithology quicklook at a more expanded scale than in track 6. Inputs are density, photoelectric effect and gamma ray or SP. The left margin is clay volume. The color scheme (inset) indicates quartz, dolomite, calcite and anhydrite values. The points remain fixed and, as clay content increases, the color tone shifts toward red.

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ment is in the measurements and answers they provide, since this information improves the geoscientist’s understanding of reservoirs and, ultimately, enhances the profitability of field developments. With nearly a year of experience so far, the influence of new data is yet to be felt fully, but early results give a sense of how this new information leads to a clearer picture of reservoir properties. Summarized here are highlights of the new technology, some common problems addressed by PLATFORM EXPRESS logs, and a recent case study from California.

Better Measurements, New Answers

PLATFORM EXPRESS technology contributes new measurements, improved processing approaches and real-time log quality controls. For all three, common features are greater accuracy, breadth of data and speed of interpretation. Many computations that formerly took place after some delay—on the surface at the wellsite after logging, or hours to days later at the log interpretation center—can now be done downhole in real time. We will look first at the measurements themselves.

From top to bottom, the platform makes seven petrophysical measurements: gamma ray, neutron porosity, bulk density, photoelectric effect (Pe), flushed zone resistivity ($R_{xz}$), mudcake thickness ($H_{mc}$), also called pad standoff, and true resistivity ($R_t$) derived from laterolog or induction imaging measurements (right).\(^1\) Integrated into the package is a z-axis accelerometer, permitting real-time speed correction (next page, top). This correction for irregular motion is performed on first-generation raw data, rather than on multisensor data that have been through one or more processing cycles, resulting in more accurate and precise real-time depth matching for all measurements (next page, bottom).\(^2\) Other measurements include caliper, mud temperature and mud resistivity and, with a special head, downhole cable tension.

Except for the gamma ray and neutron measurements, which have standard vertical resolutions, other measurements elevate the standards of wireline logging.\(^3\) In the density measurement, a reengineered pad, addition of a third detector and data processing provide improvements over conventional dual-spacing measurements.\(^4\) These improvements yield better compensation for large standoff (up to 1 in. [2.5 cm]), higher precision in denser formations and less sensitivity to barite, which compromises Pe measurements. A shorter measurement pad and

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1. Standoff refers to the distance between the pad and formation, regardless of whether this is filled with mud or mudcake. Standoff usually equals mudcake thickness in permeable formations.
3. Vertical resolution of the gamma ray and neutron porosity measurements is 24 in. [60 cm] and for the neutron up to 32 in. [30 cm] with enhanced resolution processing. See: Flaum C, Galford JE and Hastings A: “Enhanced Vertical Resolution Processing of Dual Detector Gamma-Gamma Density Logs,” The Log Analyst 30, no. 3 (May-June) 1989: 139-149.
Dramatic effect of PLATFORM EXPRESS real-time speed correction (right). In the nonreservoir section of a West Texas well, off-depth log readings were related to sticking. Lack of speed correction can lead to incorrect logs, improper correlation and, possibly, undetected pay.

Real-time resolution matched measurements, from the Middle East. The standard laterolog curve appears at far left and the highest resolution PLATFORM EXPRESS data are presented on the right. In the laterolog-type image track on the right, light bands are resistive and dark bands are conductive.
A new microresistivity technology makes measurements—three at three depths—of investigation—that are analyzed to evaluate flushed zone and mudcake properties—$R_{xo}$, $R_{mc}$, and standoff—overcoming a limitation of conventional microresistivity sensors, which can measure resistivity in the flushed zone or mudcake, but not both (see “A New Look at Microresistivity,” below). Improved focusing of this measurement helps increase $R_{xo}$ vertical resolution to 1 in. In addition, mud resistivity, typically taken with a mud cell at depth, can now be measured downhole in real time by the induction or laterolog component. The multipurpose microresistivity sensor on the platform has reintroduced, and sometimes introduced for the first time, microresistivity measurements in places where they were not used routinely, providing new insights into formation properties (below).

The induction measurement provides logs with vertical resolution of 1, 2, and 4 ft, each about two thirds that of MicroSFL measurements. Therefore it is less affected by the noninvaded zone and gives a truer $R_{xo}$ value, and hence $S_{o,x}$.

1. $R_{mc}$ is not quite an unknown. Its value is fixed by the $R_m$ value obtained by the PLATFORM EXPRESS induction or laterolog measurement.

Inversion processing is a simultaneous solution for a number of unknowns with constraints defined by the physics of the measurements. In the case of the new microresistivity log, there are three measurements of microresistivity. Rather than run each through a series of chart corrections, which leads to systematic, additive errors, the inversion program minimizes error on each output. This results in a solution that not only is more accurate, but also has a quantifiable precision.
Improving contact in rough boreholes. Hinge joints improve density-\(R_{xo}\) pad contact with the borehole wall and formation face, especially in rugose hole and washouts. Better pad contact improves measurement accuracy and interpretation in difficult boreholes.

Improved density measurement in rough hole. The conventional and new three-detector density measurements track together in smooth hole, but the shorter, better articulated pad of the new measurement gives superior results where the caliper indicates washouts (arrow). The PLATFORM EXPRESS measurement also compensates for standoff of up to 1 in. Shown here is the standard-resolution measurement.

Log-core comparison, Bakersfield, California. In this comparison, the high-resolution density confirms that 2-in. streaks seen on the microresistivity log are limey, which can act as vertical permeability barriers. Locating these streaks helps the operator identify where steam breakthrough, which can kill a producing well, will not occur and where producers can therefore be perforated closer to the water leg. Limey streaks visible in the core at X234 ft and X242 ft correspond to density peaks at those intervals.
with depths of investigation of 10, 20, 30, 60 and 90 in. In addition, an integrated mud resistivity measurement allows for accurate, real-time environmental corrections to be made. The azimuthal laterolog combines a dual laterolog array for standard deep- and shallow-resistivity measurements with an azimuthal array of electrodes that makes deep and shallow resistivity measurements around the borehole with 8- or 16-in. [40-cm] vertical resolution. The new azimuthal readings are especially helpful for interpreting horizontal well logs and invasion profiles, evaluating fractures and other formation heterogeneities, and for estimating both formation dip and resistivity of dipping beds (above). Like the induction sensor, the laterolog also measures mud resistivity in real time and downhole. New tool physics and tool design have led to better environmental corrections made in real time. For example, a new measurement of standoff in the microresistivity and density logs allows for improved environmental corrections and log quality control. In addition, measurements of mudcake Pe and bulk density permit calculation of an environmentally corrected formation Pe for better response in bad hole conditions (next page, bottom left). Real-time environmental corrections to the density log, using a temperature log, are proving valuable in steamflood regions (next page, bottom right). Temperature-corrected density and neutron logs can more reliably distinguish steam breakthrough from zones that are hot, but may still contain producible oil. Finally, measurements of downhole temperature, $R_m$ and calipers allow for real-time correction with measured, rather than estimated or derived, parameters of the borehole environment (page 15, left).

Log Quality Control
Since the dawn of well logging, the repeat run has provided proof of satisfactory tool function. Now, PLATFORM EXPRESS log quality control (LQC) procedures are giving an increasing number of operators confidence to log without the time-honored repeat run and gain significant time savings and other operational efficiencies.

Real-time log quality indicators allow monitoring of two categories of LQC data: hardware performance parameters, which indicate tool function; and data validity parameters, which are geared to indicate environmental problems that may skew readings. Functions are checked at every sampling interval, typically 6 in. [15 cm] or less. When any value falls outside a predefined limit, a solid square appears in the LQC tracks (next page, top). At the end of the log, an LQC summary reports the percentage of the logged interval with LQC values outside the defined limits. This summary provides a quick indicator of the degree of confidence in overall log quality, and the flags show whether significant problems arose in intervals critical enough to warrant a repeat run. Not usually displayed on the logs, but available to the field engineer, are diagnostics that zero in on the specific failure. Five variables each are measured for nuclear and electrical measurements—two hardware parameters, three for data validity.

In the data validity category, one example is the quality parameters for Pe measurements. The Pe measurement is sensitive to barite, and up to a point can be corrected for the influence of barite. But when the correction exceeds a certain value, the flag appears, signaling data are of limited confi-

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Interpretation of PLATFORM EXPRESS log quality measurements, which are presented as green stripes. In some provinces, the completeness of LQC data has given operators the confidence to log many wells without repeat runs. In the density and resistivity standoff curves (left track, right margin), if a threshold value is reached, a flag appears, indicating several causes—mud is too fresh for microresistivity measurements, barite is present in the mud or the density tool has been miscalibrated.

Bad hole, good logs. Depth-matched and speed-corrected PLATFORM EXPRESS logs in this Canadian well react vigorously to calcitic and shaly laminations, giving the operator a clearer understanding of the distribution of shale laminae and shale clasts, which is important in steam-injection strategy. Even the large breakout at X46 m does not dramatically distort density or Pe readings. Improved density response derives from tool articulation and a smaller pad.

Steam breakthrough or just a hot tamale? In the steamflooded fields of Bakersfield, California, a density-neutron crossover is often associated with the high temperature of steam breakthrough. However, crossover is not always a reliable indicator of breakthrough. Conventional logs may mistake a zone adjacent to steam for a zone where steam has broken through. PLATFORM EXPRESS density-neutron logs can be temperature-corrected in real time to show crossover only in zones with breakthrough. In wells of the Midway-Sunset field, use of this technique has yielded an additional 50 ft of pay, which otherwise would have been plugged. The technique relies on a temperature sensor that has a four-fold improvement in response time compared to previous technology.
Resistivity signatures of tricky sands in the San Joaquin Valley. The PLATFORM EXPRESS induction log can be presented at three vertical resolutions, from left, 1, 2 and 4 ft. The 4-ft scale can be useful for comparison with older logs, and shows how high temperature—this interval measures 200°F (93°C)—affects resistivity readings. Between X472 and X474 ft, the small bump on the 4-ft log appears to be shale. At the 1-ft scale, however, it shows a 3-ft sand with potential pay, with a high gamma ray reading due to radioactive elements concentrated in the formation from steaming. Below X480 ft, the 1-ft log reveals laminated sands that appear as a coarsening upward sequence.

For resistivity measurements, LQC diagnostics may indicate that the tool is working fine, but that environmental conditions, for example, may be responsible for an aberrant reading. This would typically be the case for the shallow-reading devices in washed-out zones, where the borehole signal would be larger than the formation signal. In the realm of hardware LQC, a flag will indicate, for instance, whether a density detector voltage is out of tolerance.

Case Study: Finding Bypassed Pay in Bakersfield

Tight margins are a way of life in the Midway-Sunset field of southern California, in one of the oldest, most productive basins in the lower 48 states. Heavy oil (10 to 15° API) lies as shallow as a few hundred feet, but production usually requires costly steamflooding. A typical well might produce 20 to 30 barrels of oil per day (BOPD) [3.2 to 4.8 m³/d] for several decades, with an exceptional producer reaching 50 barrels/day [7.9 m³/d]. Santa Fe Energy Resources, which produces more than 48,000 BOPD [635 m³/d] from three main fields in the area, faces several technical challenges.

A major challenge is identifying oil left behind after steam injection, when conventional logs sometimes present ambiguous interpretations. In a steamed zone, the density-neutron log curves may cross over because the tools read the steam, a light fraction of hydrocarbons released from the heat, or gases from in-situ combustion of hydrocarbons. The gamma ray log reads high because steam causes migration and concentration of radionuclides. High temperature lowers $R_w$, reducing apparent true resistivity—sometimes even in the presence of hydrocarbons (above). The challenge is finding oil that eludes detection conventionally.

A critical step in addressing this problem is correcting logs—in this case, the neutron, but sometimes also the $R_w$—for the high temperature. For the special needs of this field, the PLATFORM EXPRESS system was fitted with a new contact temperature sensor, which measures temperature of the formation rather than the mud. It responds four times faster than previous technologies, enabling Santa Fe Energy to acquire a high-resolution temperature measurement for a temperature-corrected neutron log (next page, left). A better fix on porosity yields a more accurate water saturation ($S_w$). A quicklook log with customized $a$, $m$ and $n$ values, and temperature-corrected neutron and $R_w$ values goes into a real-time computation of saturation. With this log, casing decisions that used to take hours can now be made in minutes.

Better understanding of desaturation yields other dividends. It leads to more effective steaming strategies, such as better identification of thief zones or intervals receiving insufficient steam. In addition, it improves completion strategies, like leaving slotted pipe in zones previously thought to be depleted of hydrocarbons, and which were formerly completed with blank pipe.

In diatomite formations of California’s San Joaquin Valley, PLATFORM EXPRESS measurements have shed new light on possible production mechanisms. These diatomites are massive, low-permeability formations that must be hydraulically fractured. Electrical imaging logs sometimes revealed high-resistivity streaks, which were not well understood. When PLATFORM EXPRESS microresistivity and $R_w$ measurements were first run, the microresistivity reported mudcake—not previously observed—and the $R_w$ showed unusual spikes (next page, right). To look for possible causes, the FMI Fullbore Formation Microlmage tool was run, which revealed mudcake and $R_w$ spikes in front of the high-resistivity streaks, suggesting that they are fractured zones. The PLATFORM EXPRESS density measurement, presented with a 2-in. vertical resolution—the highest axial resolution possible for a density measurement—indicated that the streaks are possibly cherty. This adds one more piece to the oil origins and distribution puzzle.

Santa Fe Energy has also ceased running repeat sections, due mainly to the combination of PLATFORM EXPRESS log quality data and better tool reliability. The log quality display provides enough information about tool function and wellbore conditions to confirm

10. Exponents $m$ and $n$ in the Archie formula relate oil saturation in porous rock to the resistivity of the fully water-saturated rock. The constants $a$ and $m$ relate the measured resistivity of a fully saturated porous medium to the water resistivity. Both constants are related to the nature of the connection between pore spaces; $a$, often taken as 1, is called the cementation factor, and $m$, the porosity exponent, reflects the tortuosity of the current flow through the rock pores. The saturation exponent, $n$, often taken as 2, is related to the wettability of the rock surface.
measurement validity without repeat runs. Lost time due to hardware failure is approaching 300 jobs per lost-time failure, nearly a ten-fold improvement over conventional technology. Given Santa Fe’s annual 300-well logging program, eliminating repeat logs and reducing lost-time failures translates into significant savings. Santa Fe estimates that the time savings allows more wells to be put on line, and the improved petrophysics provides better characterization of desaturated zones. Together, these benefits are expected to translate into an increase in production of more than 22,000 barrels [3180 m³] per year.

**Where It Leads**

With less than one year of commercial service, most operators are still in the handshake stage, getting to know PLATFORM EXPRESS technology. For some, a significant step is resolution-matching new logs to older logs for easier comparison, and adapting data bases to the new mnemonics. For many, the easy availability of more comprehensive wellsite answers is raising questions about long-standing formation evaluation practices. “At first we thought: ‘We don’t need microresistivity,’” said A.S. (Buddy) Wylie at Santa Fe Resources, “but we found that it could give us good additional value at only an incrementally higher price.”

The immediate and most obvious rewards are operational efficiencies. In the petrophysical realm, deeper, sharper reading and more robust measurements are showing details sometimes not seen before, whose full significance will unfold with the expanding library of PLATFORM EXPRESS logs and with the growth of interpretation techniques to get the most from them. —JMK

**A new view of possible production mechanisms in San Joaquin Valley diatomites.** An FMI log reveals high-resistivity streaks that are shown to be permeable by the PLATFORM EXPRESS microresistivity log (blue curve), and to have the high grain-density signature of chert by the 2-in. vertical resolution density log (purple curve).

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**Water saturation, with and without heatstroke.** The PLATFORM EXPRESS water saturation display (second track from right) shows a real-time $S_w$ curve corrected for the effect of temperature on the neutron input. In the right track, the corrected neutron (left margin of the green area) is offset from the uncorrected by up to about one division (6 p.u.).