OTC 25161-MS
Intelligent Casing-Intelligent Formation (ICIF) Design

Harold Stalford
Ramadan Ahmed
Victor Hugo Soriano Arambulo
University of Oklahoma
Norman, Oklahoma
OUTLINE

- Objective of ICIFT Design
- Major Telemetry Systems
- Attractive Sensing Systems
- Options for Retrieving “External Casing” Data
- Prototype ICIFT System (iBITS)
- Summary & Conclusions
Intelligent Casing/Intelligent Formation Telemetry

Objective of ICIFT Design:

- Data gathering external to casing
- More & enhance reservoir data transmitted
- Real-time data during cementing of prod. casing
- Prevent loss of well/control incident early ID
Wired/Wireless Telemetry Systems

1. Wireline System (100-500 Kb/s)
2. Wired Drill Pipe Telemetry System (50-500 Kb/s)
3. Fiber Optic System (10-100 Mb/s)
4. Mud Pulse Telemetry (1.5-40 b/s)
5. Acoustic Telemetry (10-30 b/s)
6. Electromagnetic Telemetry (10-100 b/s)
Fiber-Optic Distributive Sensing

- Distributive sensing, permanent well monitoring
- High-bandwidth, Low-loss transmission medium
- High information transmission rates \(1 \times 10^{12} \text{ b/s}\)
- No downhole electronics, immune EM radiation
- Installation any length
- Flexible configurations, greater sensitivity
- Very thin (e.g., human hair), Cheap (relatively)
Fiber-Optic Distributive Sensing

Distributive Sensing: DTS, DSS, DPS, DAS, DCS

Applications: Monitoring & Profiling:
Hydraulic fracture, well integrity, vertical seismic (VSP), gas-lift optimization, flow, sand

Coming Soon: Gas breakthrough, ESP, Micro-seismic, Multi-phase
Fiber Optic Sensors Deployed Outside Casing

Over 70 wells with DTS permanent installations
All challenges met with 100% success

Fiber deployed outside casing, cemented in place, no damage
Perforations completion without fiber damage
Control line/fiber pulled through wellhead mandrel
Integrated into “lean” drilling
Cheap enough for “low-cost” 20 BOPD environment

¹2013 SPE 163694 Rahman, et al., Aera Energy LLC
Intelligent Well Systems: Real-Time

Tubing annulus (what’s most suited, natural)
- e.g., Monitor and operate ICV components (control valves)

Casing annulus (what’s most suited, natural)
- e.g., Cement integrity, continuous formation monitoring

Philosophy:
- Keep down-hole equipment simple and reliable,
- Minimize electronics downhole,
- Restrict sensor data transmission-raw data only
- Perform processing/interpretation data at surface
ICIF Systems

Fiber-Optic Technology
- Fiber-optic distributive sensing (DTS, DPS, DAS, etc.)
- Fiber-optic network (downhole intranet)

RFID Wireless Sensing Technology
- RFID SAW Passive Sensors
- Temperature & Pressure
- RF telemetry through cement & formation media
- RF telemetry through borehole fluids

1RF through salt water (ocean): 5 MHz - 90 m - 500 Kbps
Intelligent Wellhead Design

Fiber-Optic Sensing Applications:

On-Shore:
- Tubing Annulus: Feed-throughs are standard
- Casing Annulus: Feed-throughs are in use

Off-Shore:
- Tubing Annulus: Feed-throughs are in practice
- Casing Annulus: Feed-throughs are in debate
Non-Mag-Based Wireless Wellhead Design

Provides telemetry from regions outside production casing

Ultrasonic-Based Wireless Wellhead Design

Ultrasonic Method: Communicate through carbon steel casing at wellhead

Transducers: Piezoelectric

High-power: 50 Watts ac

High-Data Trans. Rate: Over 15 Mbps through 63.5 mm Steel barriers

Cross-section of the acoustic-electric channel (courtesy of Lawry et al., 2013)

Feed-Through-Based Wellhead Design

Casing Wellhead Feed-Throughs (mod in casing hangers)
Ultrasonic Method: Communicate through carbon steel casing at wellhead

Transducers: Piezoelectric

High-power: 50 Watts ac

High-Data Trans. Rate: Over 15 Mbps through 63.5 mm Steel barriers

Cross-section of the acoustic-electric channel (courtesy of Lawry et al., 2013)
Production Casing: EM-Based Wireless Design

Special Casing Sub (Concept)
EM Wireless Communication

- Requirements: Supersedes sub-sea standards of prod. casing
- Annulus Clearance <2”
- EM Frequencies: 1-10 MHz
- External Data Transmitted:
  - Fiber-optic sensors,
  - RFID SAW, etc.
- Production Casing Integrity not adversely affected
ICIFT System Design Work

- RFID & Wireless Sensor Telemetry Tech.
- Pressure, Temperature, Flow Sensor Data
- Integrate Tech. Prototype Development
- Laboratory Test & Eval.:
- RF Signals: Cement, Formations, Fluids
ICIFT Systems Approach

“Intelligent Well” Technology Casing/Formation

Configure best wired/wireless combinations:

- In casing, on casing surface;
- In cement, in formation
- Wired sensors ; wireless sensors
- Passive sensors (no batteries); active sensors
- Distributive sensors; discrete sensors
Prototype ICIFT System (iBITS) (under development)

Two-way communication between surface command and UDW wellbore elements (continuous, real-time, high data rate)
Passive Wireless SAW Sensor
(Pressure & Temp.)

Reader (very low power)
4mW

Sensor: Temperature & Pressure
US Dime
Wireless SAW Sensor
Passive (no battery)
434 MHz

Measurements at 4mW Power Reader

<table>
<thead>
<tr>
<th>Media</th>
<th>Data Telemetry</th>
<th>Predicted Using Radar Equation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>10</td>
<td>1.4 to 2.7 ft.</td>
</tr>
<tr>
<td>Limestone</td>
<td>&gt;2</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>&gt;2</td>
<td></td>
</tr>
</tbody>
</table>
ICIFT Benefits (UDW)

Early Detection and Forecasting
- Real-time conditions of cementing jobs
- Data reduces costs and improves safety
- Data improves workover campaign

Impact on Existing Operations:
- Improve drilling & production operations
- Improve future exploration (detail information)
- Compatible with conventional completions & well intervention procedures
Summary: ICIFT Design

Options-Retrieve Data External to Casing
- Wellhead Feedthroughs (Fiber Optics, power)
- Wireless Ultrasonics (wellhead & many other locations)
- Wireless EM Wellhead (non-magnetic wellhead)
- Wireless EM Production Casing (below packer)

Distributive Sensing:
- Fiber-optic distributive sensing (DTS, DPS, DSS, DAS, DCS)

Discrete Sensing:
- Wire (host of sensors) and wireless (RFID SAW-passive, etc.)
Conclusions: ICIFT Design

Extract Data External to Casing (Cement/Formation)
- Sensors, communication networks, power (available)

Retrieve Data Extracted External to Casing
- On-shore: Feedthroughs (available)
- Off-shore (sub-sea): Use one of the Options
Acknowledgement: RPSEA Support

Thank You

Questions

1st in Oklahoma

1st in Cushing