

WellCAP Cross-Reference Tool*
UNDERBALANCED DRILLING
WCT-2UBS-X – SUPERVISORY LEVEL

| WELLCAP WCT-2UBS-X SUPERVISORY LEVEL | | REFERENCE TO APPLICATION MATERIALS (Note Where Each Topic Can Be Found) | | | |
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| I. | SIMILARITIES AND CONTRASTS BETWEEN CONVENTIONAL DRILLING AND UNDERBALANCED DRILLING | | | | |
| A. | Definitions of conventional and underbalanced drilling | | | | |
| B. | Similarities | | | | |
| C. | Differences | | | | |
| II. | UBD OVERVIEW | | | | |
| A. | Case studies | | | | |
| B. | IADC classifications | | | | |
| C. | HS&E | | | | |
| III. | UBD TECHNIQUES | | | | |
| A. | Air and natural gas drilling | | | | |
| B. | Mist drilling | | | | |
| C. | Foam drilling | | | | |
| D. | Aerated fluid drilling | | | | |
| E. | Flow drilling (gas flaring & onsite oil storage) | | | | |

* To further facilitate cross-referencing, the proposed document may include a margin or parenthetical reference to the appropriate WellCAP outline number.

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| F. | Mud cap drilling | | | | |
| G. | Snub drilling | | | | |
| H. | Production drilling (PD) | | | | |
| I. | Liquid drilling | | | | |
| IV. | DOWNHOLE CALCULATIONS FOR UBD TECHNIQUES | | | | |
| A. | Dynamic (equivalent circulating density vs. static (hydrostatic)) | | | | |
| B. | Manual – kill fluid calculations (conventional) | | | | |
| C. | Multi-phase flow modeling | | | | |
| V. | DETECTING SURFACE CONTROL PROBLEMS | | | | |
| A. | Fluid volumes at surface | | | | |
| B. | Pressure | | | | |
| C. | Determining need for conventional well control | | | | |
| D. | Elastomer considerations/flow path | | | | |
| VI. | UBD EQUIPMENT AND RIG UP | | | | |
| A. | Rotating diverter control head | | | | |
| B. | Separation equipment | | | | |
| C. | Flare line sizing and hook up | | | | |

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| D. | Flare line igniters | | | | |
| E. | Flame arresters | | | | |
| F. | Kill line hook ups | | | | |
| G. | Choke manifold hook ups | | | | |
| H. | Stripping manifolds/methods | | | | |
| I. | Choke considerations | | | | |
| J. | Drillstring floats | | | | |
| K. | BOP stack configurations | | | | |
| L. | Fluid transfer systems and level maintenance | | | | |
| M. | Onsite fluid storage systems | | | | |
| N. | Emergency well control equipment | | | | |
| O. | Standpipe manifold | | | | |
| P. | Gas vs liquid injections | | | | |
| Q. | Compromise on conventional Pit Volume Totalizer (PVT) system | | | | |
| R. | Coiled tubing | | | | |
| S. | Snubbing | | | | |
| T. | Deployment valves | | | | |
| VII. | ACCUMULATOR TESTING AND MAINTENANCE | | | | |
| A. | Scheduled maintenance | | | | |
| B. | Scheduled testing | | | | |
| C. | Written testing/maintenance report | | | | |

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| D. | Special considerations | | | | |
| VIII. | SURFACE EQUIPMENT TESTING AND MAINTENANCE | | | | |
| A. | Trapped pressure issues | | | | |
| B. | Gas vs liquid BOP stack tests | | | | |
| IX. | BOTTOMHOLE PRESSURE CONTROL | | | | |
| A. | Underbalanced margin | | | | |
| B. | Choke control and surface pressure | | | | |
| C. | Hydrostatic vs friction dominated flow | | | | |
| D. | Surface pressure limitations | | | | |
| X. | MAKING TRIPS, COMPLETIONS, LOGGING AND CONNECTIONS | | | | |
| A. | Tripping in hole | | | | |
| B. | Tripping out of hole | | | | |
| C. | Making a connection | | | | |
| D. | BHA deployment | | | | |
| XI. | PIPE "LIGHT" CALCULATIONS AND OPERATIONS | | | | |
| A. | Calculations | | | | |

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| B. | Operations | | | | |
| XII. | COMPLICATIONS WHILE DRILLING UNDERBALANCED (SUPERVISORY LEVEL ONLY) | | | | |
| A. | Excessive surface pressures and high pressure pumping consideration | | | | |
| B. | Leak in pressure control equipment | | | | |
| C. | Loss of pumping capability | | | | |
| D. | Plugged bit | | | | |
| E. | Cut out choke or manifold or plugged choke | | | | |
| F. | Loss of ability to circulate | | | | |
| G. | Bit nozzle washout | | | | |
| H. | Casing or cement failure | | | | |
| I. | Drill pipe or coil washout | | | | |
| J. | Parted drill pipe/coil | | | | |
| K. | Open hole loss of circulation | | | | |
| L. | Formation influx | | | | |
| M. | Leaking float valves | | | | |
| N. | Gas leak from BOPs to accumulator | | | | |
| O. | Critical escalating problems | | | | |
| P. | Injection line leaks | | | | |
| Q. | Hole cleaning | | | | |

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| R. | Hole stability/collapse | | | | |
| S. | Corrosion | | | | |
| T. | Down hole fire | | | | |
| U. | Foam stability | | | | |
| V. | Flash points | | | | |
| W. | Hydrogen sulfide kick | | | | |
| XIII. | IADC UBD TOUR REPORT | | | | |
| A. | Purpose and importance | | | | |
| XIV. | SITE MANAGEMENT ISSUES | | | | |
| A. | Safe explosion radius for equipment | | | | |
| B. | Crew training | | | | |
| XV. | SIMULATOR TRAINING (SUPERVISORY LEVEL ONLY) | | | | |
| A. | Drilling fluid design | | | | |
| B. | Multi-phase flow characteristics | | | | |
| C. | Problem detection and response | | | | |