

Design and Operations of the Hydrate 01 Stratigraphic Test Well, Alaska North Slope

Timothy S. Collett^{1*}, Margarita V. Zyrianova², Norihiro Okinaka³, Motoi Wakatsuki³, Ray Boswell⁴, Scott Marsteller⁵, David Minge⁶, Stephen Crumley⁶, David Itter⁶, Robert Hunter⁷

¹U.S. Geological Survey, Denver, Colorado, USA

²U.S. Geological Survey, Denver, Colorado, USA (Presenting Author)

³Japan Oil, Gas and Metals National Corporation, Chiba, Japan

⁴U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania, USA

⁵U.S. Department of Energy, Anchorage, Alaska, USA

⁶BP Exploration Alaska Inc., Anchorage, Alaska, USA

⁷Petrotechnical Resources of Alaska, Anchorage, Alaska, USA

*Corresponding Author: tcollett@usgs.gov

ABSTRACT

The National Energy Technology Laboratory, the Japan Oil, Gas and Metals National Corporation, and the U.S. Geological Survey are leading an effort to conduct an extended gas hydrate production test in northern Alaska. The proposed production test required the drilling of an initial stratigraphic test well (STW) to confirm the geologic conditions of the proposed test site. This well was completed in December 2018 in cooperation with the Prudhoe Bay Unit Interest Owners. With the success of the STW, the project leadership group is developing plans to drill a geologic data well and a production test well.

Drilling plans for the STW were advanced in late 2018. The Prudhoe Bay Unit Hydrate-01 well was spudded on 10-December-2018. Downhole data acquisition was completed on 25-December-2018 and the rig was released on 01-January-2019. The STW was drilled in two sections. The surface hole was drilled to a depth of 2248 ft (MD, measured depth) and cased, and the “production hole section” was drilled to a depth of 3558 ft (MD) and also cased. A thermally chilled mineral-oil-based mud was used to maintain drillhole stability and quality of the borehole acquired data. The primary borehole data were acquired using a suite of Schlumberger logging-while-drilling tools. To gather grain size and other data needed to inform the design of the production test well, sidewall pressure cores were collected using Halliburton’s CoreVault tool. In addition to confirming the geologic conditions at the test site, the Hydrate-01 well was designed to serve as a monitoring well during future field operations. Therefore, two sets of fiber-optic cables, each including bundled Distributed Acoustic Sensors (DAS) and Distributed Temperature Sensors (DTS), were clamped to the outside of the well casing and cemented in place. In March 2019, the project

team worked with SAExploration to acquire 3D DAS Vertical Seismic Profiling (VSP) data in the Hydrate-01 well, which was the largest 3D DAS-VSP ever conducted. Additionally, since the December 2018 completion of the STW, several borehole temperature surveys have been acquired with the DTS deployed in the Hydrate-01 well.

Keywords: gas hydrates, natural gas, Alaska North Slope, logging-while-drilling, coring, drilling operations, production testing, monitoring

1. INTRODUCTION AND BACKGROUND

Gas hydrates are naturally occurring, ice-like solids in which water molecules trap gas molecules in a cage-like structure known as a clathrate. The Alaska North Slope (ANS) has long been a focus for gas hydrate research. In 2019, the U.S. Geological Survey (USGS) published an updated assessment of technically recoverable gas hydrate resources in northern Alaska, estimated at 54 trillion cubic feet of natural gas that could be recovered from hydrate-bearing formations throughout the region (Collett et al., 2019). One of the most studied permafrost-associated gas hydrate accumulations has been the Eileen Gas Hydrate Trend on the Alaska North Slope (Collett et al., 2011; Boswell et al., 2016; Boswell et al., 2020), which was the target of the December 2018 gas hydrate stratigraphic test well (STW) as reviewed in this report.

In 2015, a team of scientists from the U.S. Department of Energy (DOE), the Japan Oil, Gas and Metals National Corporation (JOGMEC), and the USGS, with assistance from the Alaska Department of Natural Resources, discovered a promising site within the Prudhoe Bay area on the ANS. The site featured an existing, but unused, gravel pad adjacent to an existing road (Figure 1) overlying a gas hydrate accumulation that



Figure 1. Image of the 7-11-12 pad in the western part of the Prudhoe Bay Unit (PBU). The 7-11-12 pad is located immediately adjacent to the PBU Spine Road. The physical “footprint” of the Parker 272 drilling rig and mud chiller system, used to drill the Hydrate-01 Stratigraphic Test Well, is shown in blue.

appeared to be in a geologic configuration suitable for an extended gas hydrate production test (Okinaka et al., 2020). From 2017 to 2019, the team developed an operational drilling plan that enabled the needed science to be conducted in a manner that would not disrupt industry’s ongoing field operations in the area.

After an extensive planning effort, the project partners moved forward with a STW, named the Hydrate-01 well, which was drilled and completed in December 2018 by BP Exploration Alaska Inc. (BPXA) as the Prudhoe Bay Unit Operator. BPXA drilled the well using the Parker 272 rotary drilling rig through a Drilling Services Agreement executed with Petrotechnical Resources of Alaska (PRA) in association with a contract between DOE and PRA. The STW met all project objectives and confirmed the occurrence of highly saturated gas hydrate-bearing reservoirs (Boswell et al., 2020), which were designated Unit B and Unit D by Collett et al. (2011).

Unit B, the deeper of the two reservoirs, comprises well-sorted, very fine-grained sand to coarse-silts. The hydrate was interpreted to be filling 65 percent to more than 80 percent of the porosity in the upper 40 feet of Unit B (Boswell et al., 2020; Haines et al., 2020; Suzuki et al., 2019). Unit D, the shallower of the two reservoirs, exhibits similar gas hydrate saturations to that observed for Unit B. In addition, Unit D has a water-bearing section at its base, which could provide opportunities to investigate additional scientific and well design options as a potential follow-on to the testing of the primary Unit B target (Suzuki et al., 2019; Boswell et al., 2020; Haines et al., 2020).

The STW was the initial phase of a program designed to conduct an extended duration test of the response of gas hydrate reservoirs to controlled depressurization. The actual production testing phase of this project is intended for early 2021 (Okinaka et al., 2020).

This report provides an overview of the operational aspects of the Hydrate-01 STW, including: (1) pre-drill site selection process, (2) pre-drill project and operational planning, (3) review of drilling operations, (4) synopsis of the completed logging-while-drilling (LWD) operations, (5) acquisition of sidewall pressure cores, (6) a review of the well completion including the installation of fiber-optic monitoring cables, and (7) an analysis of the major lessons learned from the operational review of the Hydrate-01 well.

2. PRE-DRILL SITE SURVEY AND SELECTION PROCESS

From early 2015 through 2017, a research team led by DOE, JOGMEC, and the USGS, along with support from the Alaska Department of Natural Resources, worked to identify a potential location and develop a plan for an extended gas hydrate production test on the ANS. This effort included a comprehensive review of potential testing sites within unleased acreage adjacent and to the north of the Prudhoe Bay Unit (PBU). These locations were determined to have unfavorable geologic, logistical, and operational risks as compared to known sites within the western part of the PBU (Boswell et al., 2020; Okinaka et al., 2020).

The test site selection was based upon accessibility, proximity to North Slope infrastructure, and confidence in the presence of gas hydrate-bearing reservoirs and the possibility of multiple reservoir targets. The target for this field test was high porosity, high (intrinsic) permeability clastic sand-rich reservoirs in the Tertiary Sagavanirktok Formation (Collett et al., 2011; Boswell et al., 2020). For the field test, reservoirs below the permafrost with an in situ temperature no lower than 40°F were targeted. Wireline-deployed well logs, as acquired from industry exploratory and development wells, were the primary dataset used to identify and evaluate potential gas hydrate reservoir targets.

The site review and selection process determined that the western part of the PBU was a location that combined known and possible gas hydrate occurrences with an existing gravel pad and no ongoing industry activities; this was the gravel pad at the site of the Kuparuk 7-11-12 exploration well (Figure 1). The pad lies at the intersection of the main PBU Spine Road and the road to the PBU Z-Pad to the south. As part of the well-planning effort, a portion of an industry-acquired 3D seismic data

volume was made available to the project partners through agreements with PBU Working Interest Owners, which allowed for more detailed mapping of the potential hydrate reservoir sections in the area of the gravel pad from which the Kuparuk 7-11-12 exploration well was drilled (Boswell et al., 2020; Lim et al., 2020).

3. PRE-DRILL PROJECT AND OPERATIONAL PLANNING

The gas hydrate accumulations in the western part of the PBU occur within the Tertiary Sagavanirktok Formation. The Project Partner site review process indicated that two hydrate-bearing stratigraphic units (Units B and D) had the potential to be encountered with suitable reservoir conditions to conduct the desired gas hydrate testing. These reservoirs are well known from log data acquired at the NW Eileen State-2 well in 1970, from log and other data acquired at the Igñik Sikumi test well in 2012, from log data acquired in the Kuparuk 7-11-12 well, and from log data acquired in numerous industry exploratory and development wells drilled throughout the PBU, Milne Point Unit, and the Kuparuk River Unit (Collett et al., 2011). Despite the available log data from the Kuparuk 7-11-12 exploration well, geologic risk remained with respect to the condition of the target reservoirs. It was determined that a STW would be required to confirm reservoir occurrence and condition (Okinaka et al., 2020).

In 2018, BPXA proposed to operate the ANS Hydrate-01 well in cooperation with the PRA-lead project team as a means to “warm up the rig” to be used for the PBU 2019 industry drilling program. The operational plan for the Hydrate-01 STW was developed under a modified version of the BPXA “Decision Support System,” which featured the development of a “Statement of Requirements” (SOR) document that specifically describes the project objectives and requirements (Okinaka et al., 2020). The primary objectives of the Hydrate-01 well included the following:

- Confirm the presence, temperature, thickness, reservoir saturation, and grain size of gas hydrate-bearing Sagavanirktok Units B (primary target), C, and D (secondary targets) in the target area in order to determine if the area is suitable for a future gas hydrate production test well and a hydrate data collection well.
- If a suitable gas hydrate accumulation is confirmed, complete the STW as a monitoring well for the future production testing phase of the project. If logging data do not indicate sufficient hydrate presence, abandon the well.

Upon approval of the SOR by all stakeholders, the engineering design, contracting, and permitting phases of

the project were performed by PRA and the research partnership under the operatorship of BPXA.

4. HYDRATE-01 DRILLING OPERATIONS

The Drilling and data acquisition operations were conducted in the Hydrate-01 STW from the acceptance of the Parker 272 drilling rig on 05-December-2018 through the release of the drilling rig on 01-January-2019 (Figure 2). Program objectives were to acquire geologic and engineering data including sidewall pressure cores, LWD data, wireline-acquired log data (as a backup to LWD data, if required), and the deployment of formation monitoring systems pending the confirmation of suitable gas hydrate accumulations for production testing.

The Hydrate-01 well was initially drilled as a vertical well to a depth of about 600 ft measured depth (MD) and then deviated to target a bottom hole location about 1000 ft to the northeast of the well’s surface location on the Kuparuk 7-11-12 gravel pad (Figure 3). The Hydrate-01 well was completed to a total depth of 3558 ft MD (3290 ft true vertical depth subsea; TVDss).

Much like typical industry wells on the ANS, the Hydrate-01 drilling operations included the installation of surface casing below the permafrost section to help maintain borehole stability (Figure 4). The 9-5/8” surface casing was landed and cemented in place to a depth of 2440 ft MD. The 8-1/2” production hole section was drilled with refrigerated (chilled) mineral oil-based mud (MOBM) drilling fluid to limit the dissociation of in situ gas hydrate and to maintain in-gauge borehole conditions to enable the acquisition of high-quality LWD data and sidewall pressure cores. The MOBM was cooled to a targeted temperature ranging from 15 to 35°F by circulating the drilling fluids through a heat-transfer chilling unit connected to the Parker 272 drilling rig. Mud logging-acquired drill cuttings samples and gas geochemistry data were collected within both the surface and production hole section of the Hydrate-01 well for real-time geologic characterization, archival storage of drill cuttings samples, and to fulfill USGS geochemical sampling requirements and protocol.

In support of the primary objectives of the Hydrate-01 STW, LWD tools were included within the bottom-hole assemblages (BHA) used to drill both the surface hole (12-1/4” hole) and production hole (8-1/2” hole) sections of the STW to enable the assessment of the targeted reservoir units (Table 1) as reviewed later in this report. The downhole logging program also included a contingency open hole wireline logging program. Contingency wireline logging was included in the well plan to deal with the possibility that the LWD data proved to be insufficient to characterize the presence of hydrates in the target intervals. Ultimately, the analysis of the LWD-acquired logging data confirmed the occurrence of

gas hydrate and suitable reservoir conditions for production testing in both Unit B and Unit D, thus eliminating the need for contingency wireline logging. The determination of suitable reservoirs for testing also led to the decision to move ahead with the acquisition of sidewall pressure cores (Yoneda et al., 2020) and the installation of casing with fiber-optic cables for the measurement of formation temperatures and the acquisition of acoustic geophysical data (Lim et al., 2020).

Pressurized sidewall core samples were acquired from the reservoir and non-reservoir stratigraphic section associated with Units B and D (Table 2; Yoneda et al., 2020) in the Hydrate-01 STW as reviewed later in this report. The Hydrate-01 STW well was also outfitted with continuous fiber-optic monitoring cables, which were used to acquire a 3D vertical seismic profile (VSP) after the completion of the well (Lim et al., 2020). These same cables will be used to monitor downhole temperature conditions and acquire additional 3D VSP data throughout the remainder of the gas hydrate testing program.

After the completion of the production hole section of the Hydrate-01 well with the running and cementing in place the 5-1/2" production casing to a depth of 3548 ft MD (Figure 4), a wireline deployed gyroscope directional survey tool was run in the 5-1/2" casing to acquire highly accurate downhole well placement information. In addition, thermally insulating fluid was placed inside the casing, a bridge plug was set at 2390 ft MD (Figure 4), a 3-1/4" abandonment tubing was run to a depth of 2383 ft MD, and cement was pumped to fill the casing and tubing from the bridge plug to the surface.

It is important to highlight that the Hydrate-01 well was completed without any recordable safety incidents. When considering the overall drilling and associated operational performance of the Hydrate-01 well (Figure 2), the pre-drill estimated 22.1-day program plan was exceeded by 5.6 days. The recordable "non-productive time" associated with Hydrate-01 operations can be mostly attributed to (1) an operational stand-down due to field operations outside the scope of this project, (2) unplanned surface casing completion "top job" remediations, and (3) performance issues associated with the mud chiller system. These issues are discussed in greater detail in Section 8 of this report: "Operational Lessons Learned."

5. HYDRATE-01 LOGGING-WHILE-DRILLING OPERATIONS

The primary well data obtained from the Hydrate-01 well featured the acquisition of a full suite of Schlumberger LWD and measurement-while-drilling (MWD) well logs (Table 1). LWD/MWD operations in

the 12-1/4" surface hole included the deployment of arcVISION, SadnVISION, Sonic Scope, and TeleScope tools. The LWD/MWD program in the 8-1/2" production hole section included the deployment of arcVISION, adnVISION, Sonic Scope, proVISION, and TeleScope

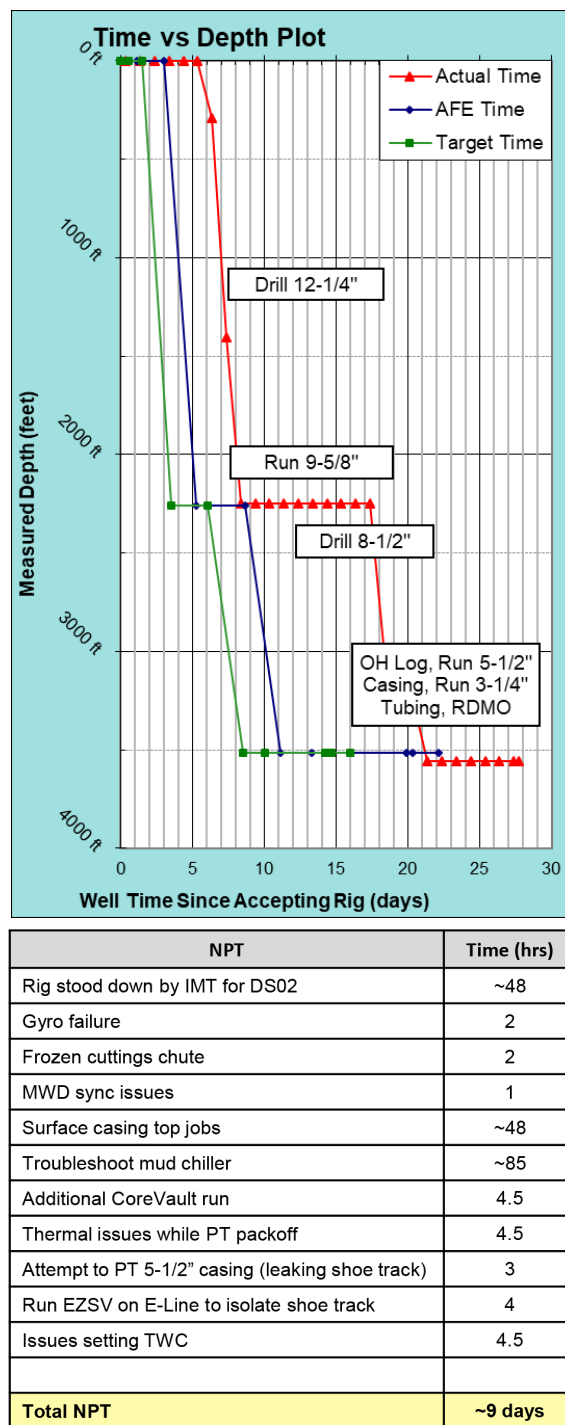


Figure 2. Drilling and operational performance analysis of the Hydrate-01 Stratigraphic Test Well. Shown is the actual well schedule as compared to the pre-drill well plan. AFE = Authorization for expenditure, IMT = Incident Management Team, NPT = Non-productive time, PT = Pressure transmitter, TWC = Two-way communication

tools. The LWD/MWD program in the 8-1/2" production hole section included the deployment of arcVISION, adnVISION, Sonic Scope, proVISION, and TeleScope tools. Table 1 contains a complete summary of Schlumberger LWD tools that were run in the Hydrate-01 STW along with the depth of each LWD log run. The primary log run in the 12-1/4" surface hole was Run LWD001. Drilling/logging operations in the 8-1/2" production hole section were conducted in two parts: Runs LWD003 and LWD004. As shown in Table 1, the three primary log runs in the Hydrate-01 (i.e., LWD001, LWD003, and LWD004) each included additional measurement-after-drilling (MAD) up-hole running surveys to acquire additional repeat log data over important and/or anomalous stratigraphic intervals.

Due to the careful control of drilling rates, the use of MOBM, and attention to maintaining cold mud temperatures throughout the drilling process, the 8-1/2" production hole section was in very good condition resulting in outstanding LWD data quality. The acquisition of a full suite of high-quality MWD/LWD data, including gamma-ray, resistivity, acoustic, and nuclear magnetic resonance (NMR) well logs enabled the assessment and confirmation of the occurrence of gas hydrate in the targeted Unit B and Unit D reservoirs (Suzuki et al., 2019; Boswell et al., 2020; Haines et al., 2020), achieving one of the primary objectives of the Hydrate-01 STW.

6. HYDRATE-01 ACQUISITION OF PRESSURE CORES

To gather grain size and other data needed to inform the design of the production test well, sidewall pressure cores were collected in the Hydrate-01 STW using Halliburton's CoreVault tool (Okinaka et al., 2020; Yoneda et al., 2020). After the 8-1/2" production hole was advanced to a depth of 3260 ft MD, the CoreVault tool was run to obtain pressurized sidewall cores from the hydrate-bearing portions of Units B and D, along with additional core samples from the non-reservoir shale bounding stratigraphic sections associated with Units B and D. A total of 34 cores were successfully recovered during five runs of a wire-line deployed pressure corer in the Hydrate-01 STW (Table 2). A total of 13 pressure core samples were extracted, preserved in liquid nitrogen, and shipped to the laboratories of the National Institute of Advanced Industrial Science and Technology in Sapporo, Japan, for advanced laboratory analysis (Yoneda et al., 2020). The remaining 21 core samples were shipped to the Weatherford lab in Golden, Colorado, for routine and advanced core analysis.

7. HYDRATE-01 WELL COMPLETION AND MONITORING SYSTEM

With the confirmation of gas hydrate-bearing reservoirs within the Hydrate-01 STW, the decision was made to move ahead with the conversion of the Hydrate-01 STW to a monitoring well. This conversion included outfitting the well with continuous fiber-optic monitoring cables (clamped the casing and cemented in place). Two redundant sets of Distributed Temperature Sensors (DTS) and Distributed Acoustic Sensors (DAS) fiber-optic cables were clamped to the outside of the 5-1/2 inch production casing (Figure 4), deployed to the bottom of the hole, and cemented in place. This installation completed the second major objective of the Hydrate-01 drilling program as defined within the project SOR. The DTS was used to collect formation temperatures over the entire length of the Hydrate-01 well through 14-March-2019. Additional temperature profiles were obtained on 28-June-2019 and continuous DTS monitoring was started in December 2019. The deployed DAS cables

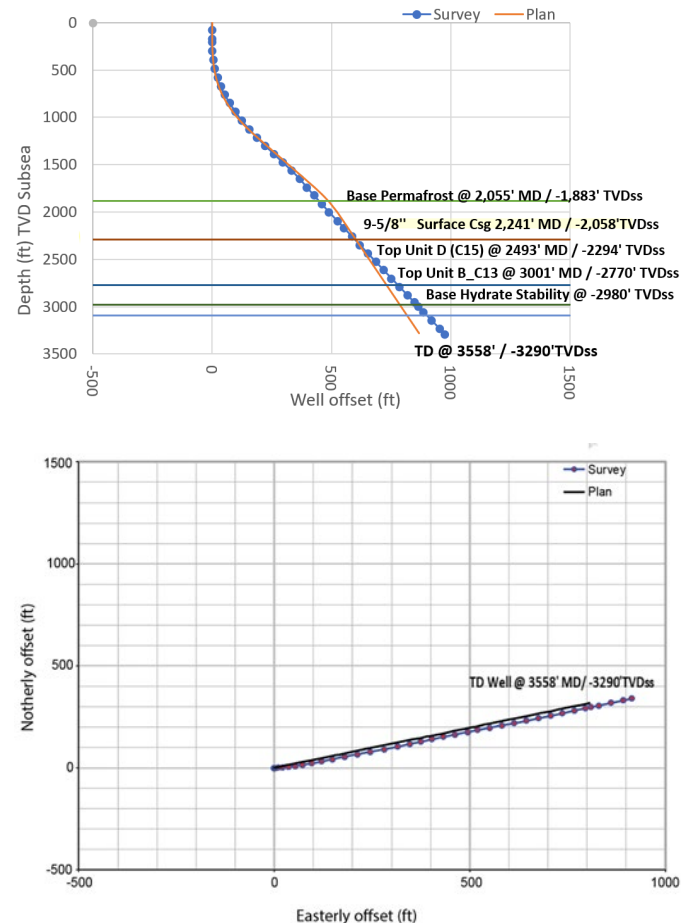


Figure 3. End-of-well vertical section image of the Hydrate-01 Stratigraphic Test Well profile; shown is the completed well path (Survey) for the well in both map and cross-section view relative to the original well design (plan). Also shown are the depths of the major well targets and features. Csg = Casing

BHA	LWD Log Run	Hole Section	Comments	Date Started	Date Finished	MWD Top (ft MD)	MWD Bottom (ft MD)	MAD Top (ft MD)	MAD Bottom (ft MD)	LWD and MWD Tools Primary Measurements
1		12.25 in	No data							
2	LWD001	12.25 in	Drill to casing point	11-Dec-18	13-Dec-18	318.25	2205	100	318.25	arcVISION 825 (gamma ray, resistivity) TeleScope 825 MWD (survey-power-com) SonicScope 825 (acoustic velocity) SadnVISION (neutron-density porosity)
3		12.25 in	No data: Clean Out							
4	LWD002	8.5 in	No data: Remove RSS							
5	LWD003	8.5 in	Drill to core point	20-Dec-18	23-Dec-18	2205	3224	2229.75	3256.83	arcVISION 675 (gamma ray, resistivity) TeleScope 675 MWD (survey-power-com) SonicScope 675 (acoustic velocity) proVISION 675 (NMR) adnVISION (neutron-density porosity)
6	LWD004	8.5 in	Drill to TD	25-Dec-18	26-Dec-18	3224	3522	2726	3160	arcVISION 675 (gamma ray, resistivity) TeleScope 675 MWD (survey-power-com) SonicScope 675 (acoustic velocity) proVISION 675 (NMR) adnVISION (neutron-density porosity)

Table 1. Logging-while-drilling (LWD) and measurement-while-drilling (MWD) program as completed in the Hydrate-01 Stratigraphic Test Well. com = communication, in = Inch, MAD = Measurements-After-Drilling, MD = Measured depth, NMR = Nuclear Magnetic Resonance, RSS = Rotary steerable system, TD = Total depth of well drill.

were used in March 2019 to obtain a large 3D VSP dataset over the site of the proposed gas hydrate production test (Lim et al., 2020).

8. OPERATIONAL LESSONS LEARNED

At the end of the Hydrate-01 STW project, BPXA convened an “End of Well Review” which included the analysis of the lessons learned based on actionable conclusions about what went right, what went wrong, and what could be done to better prepare for future operations. The major actionable lessons learned from the Hydrate-01 STW operations included the following:

- Directional drilling vendor delivered the planned directional drilling program, despite removing the rotary steerable system (RSS) from the BHA.
- Drilling fluids vendor successfully ran the oil-based mud system with no issues; the rig team handled the mud without any contamination problems.
- The volume of surface casing cement was insufficient and did not circulate to surface due to likely considerable surface hole enlargement within the ice-bearing permafrost section, causing the need for surface casing “top jobs.”
- The time required for the unplanned surface casing cement “top job” remediations were impacted by the lack of 24-hour coverage of the cement crew and lack of available lightweight cement on the ANS. Additionally, the time needed to develop the required compressive strength of the pumped cement was longer than anticipated, thus indicating the need for additional “pilot testing” of all cement products.
- The performance issues associated with the mud chiller system was attributed to the fact that the impact of a reduced internal mud chiller flowrate was not fully appreciated; additional flow-rate sensitivity analysis should help

understand the effect of the flow regime on the performance of the mud chiller system. For future projects, include both active (primary system) and passive (backup system) mud chiller systems.

- Improve ability to monitor mud temperature in digital format at various locations on the rig (i.e., before/after mud pumps, possum belly, pits, etc.).
- Despite causing drilling delays, the deployed mud chiller system was able to adequately cool mud and provide the conditions for obtaining excellent LWD data and sidewall pressure cores.
- The equipment configuration used to run and cement the 5-1/2” production casing was successful in delivering the second primary well objective to deploy DTS/DAS monitoring system.
- The lack of lead-time restricted equipment options and added cost (planning for equipment orders should begin about 8-12 months before the start of operations).

9. FUTURE PROJECT PLANS

With the successful confirmation of the presence of hydrate-bearing reservoir sections suitable for production testing at the site of the Hydrate-01 STW, the current goal of the ANS gas hydrate production testing effort is to partner with an operator for the planned production test (Okinaka et al., 2020). The project partners will work with the selected operator to finalize the design of the remaining wells, surface production facilities, and testing procedures to allow the implementation of efficient and safe scientific production testing and monitoring that will address a range of questions associated with the response of gas hydrate-bearing reservoirs to depressurization. The

plan is to conduct a long-term (1-year minimum) scientific reservoir response test utilizing depressurization production technology, possibly starting in early 2021. These activities will provide an initial assessment of the potential to successfully produce gas hydrates resources in similar settings throughout the U.S. and the world.

Core Run and Core Number	Core Depth (ft MD)	BP Sample ID	BP Sample Depth (ft MD)	Stratigraphic Unit	Assigned Laboratory
1 - 2	3,006.01	1-2	3,006.00	Unit B	Weatherford
1 - 3	3,007.04	1-3	3,007.00	Unit B	Weatherford
1 - 4	3,008.05	1-4	3,008.00	Unit B	Weatherford
1 - 5	3,009.05	1-5	3,009.00	Unit B	Weatherford
1 - 6	3,011.02	1-6	3,011.00	Unit B	Weatherford
1 - 7	3,013.08	1-7	3,013.00	Unit B	Weatherford
1 - 8	3,015.01	1-8	3,015.00	Unit B	Weatherford
1 - 10	3,019.02	1-10	3,019.00	Unit B	Weatherford
1 - 12	3,023.05	1-12	3,025.00	Unit B	Weatherford
1 - 13	3,026.03	1-13	3,027.00	Unit B	Weatherford
2 - 1	3,032.00	2-18	3,032.00	Unit B	Weatherford
2 - 2	3,033.01	2-19	3,033.00	Unit B	Weatherford
2 - 3	3,035.05	2-20	3,035.00	Unit B	AIST
3 - 1	2,498.02	3-22	2,498.00	Unit D	AIST
3 - 2	2,501.07	3-23	2,501.00	Unit D	AIST
3 - 3	2,501.07	3-24	2,504.00	Unit D	Weatherford
3 - 4	2,504.15	3-25	2,507.00	Unit D	AIST
3 - 5	2,511.04	3-27	2,511.00	Unit D	AIST
3 - 6	2,513.05	3-28	2,513.00	Unit D	Weatherford
3 - 7	2,516.07	3-29	2,516.00	Unit D	AIST
3 - 8	2,519.03	3-30	2,519.00	Unit D	AIST
3 - 9	2,522.06	3-31	2,522.00	Unit D	Weatherford
3 - 10	2,525.10	3-32	2,525.00	Unit D	AIST
4 - 1	3,010.04	4-33	3,010.00	Unit B	AIST
4 - 2	3,014.09	4-34	3,014.00	Unit B	Weatherford
4 - 3	3,016.04	4-35	3,016.00	Unit B	AIST
4 - 4	3,018.04	4-36	3,018.00	Unit B	AIST
4 - 5	3,024.02	4-38	3,024.00	Unit B	AIST
4 - 6	3,040.01	4-39	3,040.00	Unit B	AIST
5 - 1	3,078.07	5-44	3,078.00	Lower Seal	Weatherford
5 - 2	3,074.03	5-45	3,074.00	Lower Seal	Weatherford
5 - 3	3,070.02	5-46	3,070.00	Lower Seal	Weatherford
5 - 4	Unknown	Unknown	Unknown	Lower Seal	Weatherford
5 - 5	Unknown	Unknown	Unknown	Lower Seal	Weatherford

Table 2. Listing of sidewall pressure cores recovered in the Hydrate-01 Stratigraphic Test Well using the Halliburton CoreVault system. Also shown is the laboratory each core was assigned to, AIST = National Institute of Advanced Industrial Science and Technology in Sapporo, Japan; Weatherford = Weatherford core lab in Golden, Colorado, U.S.

10. CONCLUSIONS

The Hydrate-01 STW that was drilled in support of a proposed ANS gas hydrate production test project was completed in December 2018 with the following major results:

- The Hydrate-01 well was drilled without any recordable incidents or injuries.
- The well confirmed the occurrence of gas hydrate in two targeted reservoir sections.

- A complete research-level suite of LWD downhole log data was acquired in the Hydrate-01 well, which confirmed the presence of two high-quality reservoirs, each with high gas hydrate saturations that are suitable for gas hydrate production testing.
- The targeted reservoirs were determined to be acceptable for production testing; therefore, the DTS and DAS systems were installed in Hydrate-01, allowing the well to serve as a monitoring well for future testing.
- Pressurized sidewall cores were recovered from both targeted gas hydrate reservoir units and their associated seals. Results of laboratory analysis of the petrophysical and geomechanical properties of the recovered sidewall pressure cores will be used to design the completion requirements for the proposed future test wells.

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12. REFERENCES

- Boswell, R., Collett, T., Suzuki, K., Yoneda, J., Haines, S., Okinaka, N., Tamaki, M., Crumley, S., Itter, D., Hunter, R., 2020. Alaska North Slope 2018 Hydrate-01 Stratigraphic Test Well: Technical Results, Proc. ICGH-10, Singapore.
- Boswell, R., Schoderbek, D., Collett, T., Ohtsuki, S., White, M., Anderson, B., 2016. The Ignik Sikumi field experiment, Alaska North Slope: design, operations, and implications for CO₂-CH₄ exchange in gas hydrate reservoirs. *Energy & Fuels* 31 (1), 140-153.
- Collett, T., Lee, M., Agena, W., Miller, J., Lewis, K., Zyrianova, M., Boswell, R., Inks, T., 2011. Permafrost-associated natural gas hydrate occurrences on the Alaska North Slope. *J. Marine and Petroleum Geology* 28, 279-294.
- Collett, T.S., Lewis, K.A., Zyrianova, M.V., Haines, S.S., Schenk, C.J., Mercier, T.J., Brownfield, M.E., Gaswirth, S.B., Marra, K.R., Leathers-Miller, H.M., Pitman, J.K., Tennyson, M.E., Woodall, C.A., and Houseknecht, D.W., 2019. Assessment of undiscovered gas hydrate resources in the North Slope of Alaska, 2018: U.S. Geological Survey Fact Sheet 2019-3037, 4 p.
- Haines, S., Collett, T., Boswell, R., Lim, T-K., Okinaka, N., Suzuki, K., Fujimoto, A., 2020. Gas hydrate saturation estimation from acoustic log data in the 2018 Alaska North Slope Hydrate-01 Stratigraphic Test Well, Proc. ICGH-10, Singapore.
- Lim, T.K., Fujimoto, A., Kobayashi, T., 2020. DAS-3DVSP data acquisition at 2018 Stratigraphic Test Well (Hydrate-01). Proc. ICGH-10, Singapore.
- Okinaka, N., Boswell, R., Collett, T., Yamamoto, K., Anderson, B., 2020. Progress toward the establishment of an extended

duration gas hydrate reservoir response test on the Alaska North Slope. Proc. ICGH-10, Singapore.

Suzuki, K., Collett, T., Boswell, R., Tamaki, M., Okinaka, N., Sato, D., 2019. Interpretation of logging data from the Hydrate-01 Stratigraphic Test Well drilled in the Prudhoe Bay Unit, Alaska North Slope. Proc. American Geophysical Union Fall Meeting, San Francisco, CA, Dec 10, 2019.

Yoneda, J., Jin, Y., Muraoka, M., Oshima, M., Suzuki, K., Walker, M., Westacott, D., Ohstuki, S., Kumagai, K., Collett, T., Boswell, R., Okinaka, N., 2020. Petrophysical and geomechanical properties of gas hydrate-bearing sediments recovered from Alaska North Slope 2018 Hydrate-01 Stratigraphic Test Well. Proc. ICGH-10, Singapore.

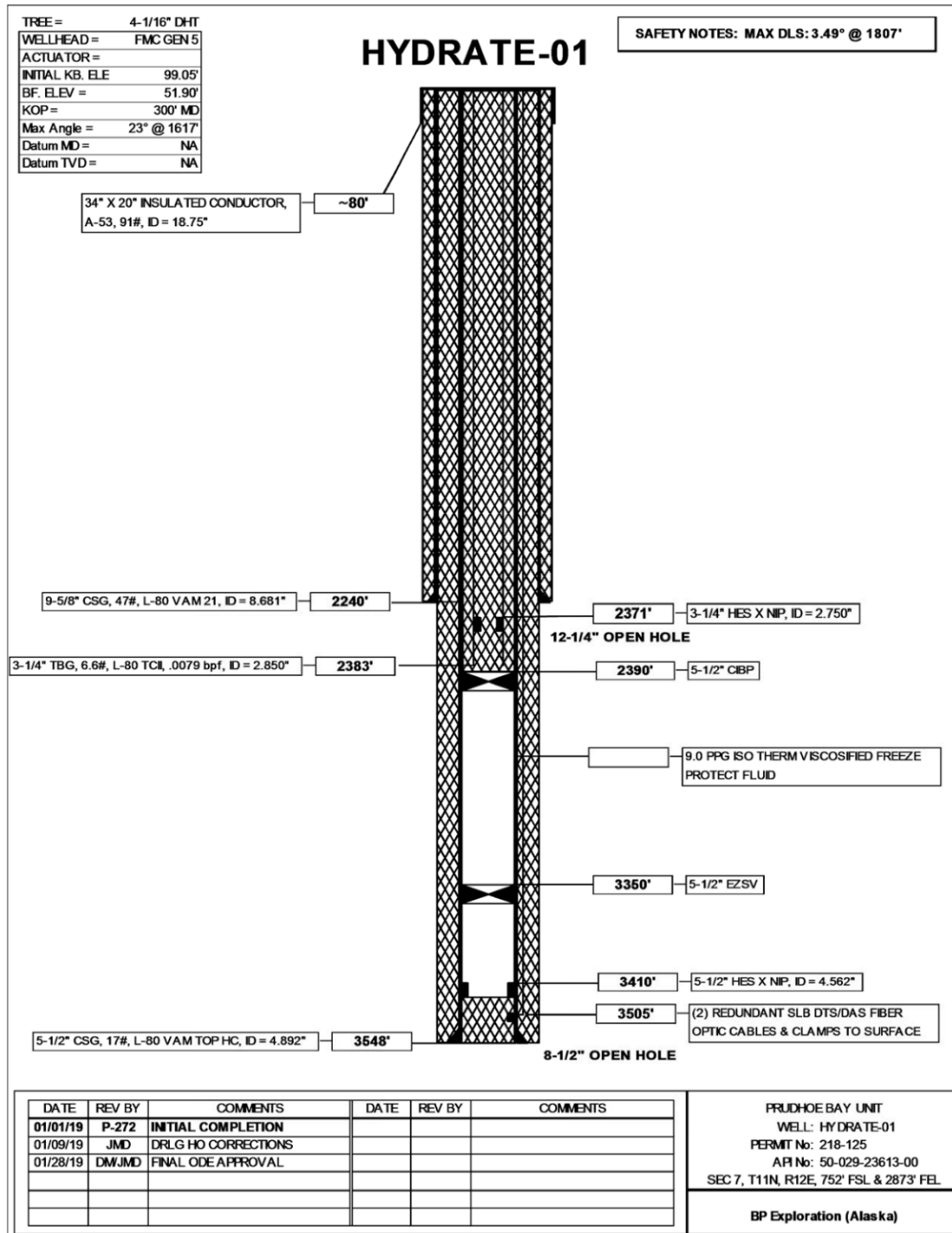


Figure 4. Engineering completion of the Hydrate-01 Stratigraphic Test Well depicting how the well was drilled and completed.